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ISSUE 150
DECEMBER 2023

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WELCOME

ISSUE 150

This issue marks a special one: **All About Space** is 150 issues old! Whether you've been with us since issue 1, issue 50 or have only just picked us up, we hope that you've enjoyed every moment of exploring the universe as much as we have. This month, we're bringing you a bumper-packed feature chronicling the most outstanding discoveries we've made throughout our history of studying the cosmos. Selected by experts at NASA, the ESA and other top space organisations around the world, did your favourite make the list?

And we're not stopping there. If you're yet to complete your Christmas shopping, we have the ultimate gift guide for the space enthusiast in your life. If you have a telescope on your wishlist but you're not quite sure which kind is right for you, then flick through our feature in mastering the art of choosing the perfect instrument. Our team of astronomers also answer your stargazing questions, particularly around telescope jargon and troubleshooting during your observations of the night sky.

Lastly, a very Merry Christmas from the team at **All About Space**, and we'll see you again in the New Year!

GEMMA LAVENDER
Editor

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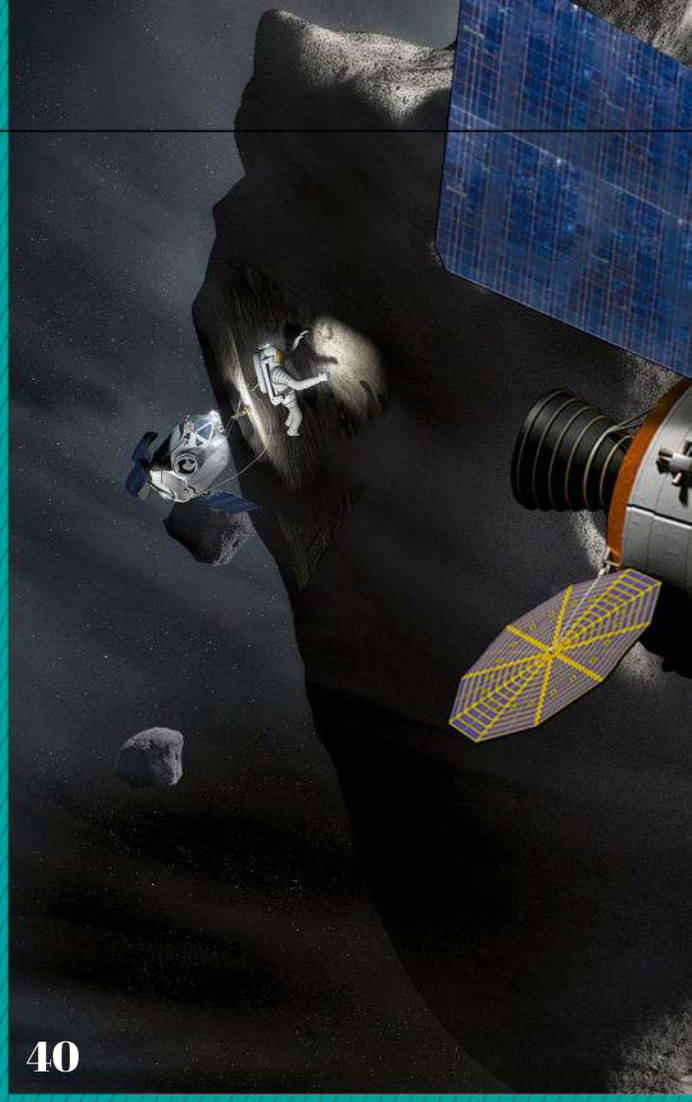
ALL ABOUT SPACE
ISSUE 151
ON SALE 28 DECEMBER

INSIDE

20 150 GREATEST DISCOVERIES



40

LAUNCHPAD

06 News from around the universe

FUTURE TECH

40 Manned mission to an asteroid

Sending manned expeditions to near-Earth asteroids will help us discover more about their formation and structure

INTERVIEW

42 Geoff Notkin

The world expert on meteorites and presenter of award-winning adventure TV series *Meteorite Men* talks of his ongoing search for space rocks

FOCUS ON

46 China is building the world's largest underwater telescope to hunt for 'ghost particles'

FOCUS ON

50 The home of the world's most powerful telescopes joins the fight against light pollution

52 Why does Venus look so young?

Unlike Earth, Venus only has one continuous plate. Scientists have long been trying to work out why Earth's 'evil twin' has a high level of volcanism

FOCUS ON

58 'Air showers' could help reveal cosmic rays' mysterious sources

60 Ask Space

Your questions answered by our panel of experts

60

FOCUS ON

64 A mud lake on Mars might be hiding signs of life in chaotic terrain

FOCUS ON

68 Infrared aurorae on Uranus confirmed for the first time

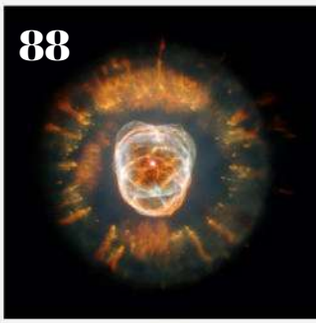
70 Your guide to the perfect telescope

You've decided to buy a new instrument, but which one should you get?

"It took me years to find my second!"

Geoff Notkin

42



STARGAZER

80 What's in the sky?

82 Planetarium

84 Month's planets

86 Moon tour

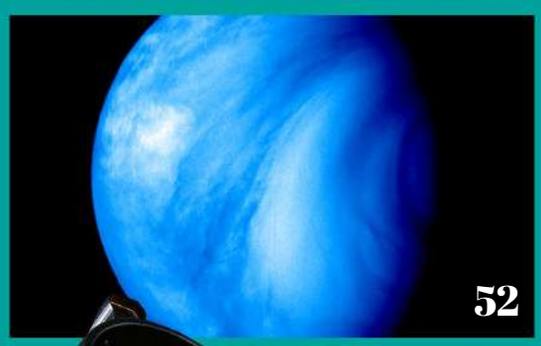
87 Naked eye & binocular targets

88 Deep sky challenge

90 The Northern Hemisphere

92 Review

96 In the shops



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23 October 2023

An unexpected galactic trio

A new image from the Hubble Space Telescope reveals a galaxy overshadowed by its larger merging companions. Located roughly 500 million light years from Earth lies a galactic pair collectively known as Arp-Madore 2339-661. The two galaxies are in the process of merging. One galaxy is known as NGC 7733 – the smaller galaxy seen in the lower right – and the other is NGC 7734, the larger galaxy in the upper left. However, hidden in the star-studded spiral arm of NGC 7733 is yet another galaxy, referred to as NGC 7733N.

Until now, this realm has been obscured by dark dust. Using the new Hubble data, however, astronomers were able to discern a knot-like structure with a notable red glow, standing out in comparison to the bright-blue stars of NGC 7733. "This could easily pass as part of NGC 7733, but analysis of the velocities involved in the galaxy shows that this knot has a considerable additional redshift, meaning that it's very likely its own entity and not part of NGC 7733," European Space Agency (ESA) officials said.

The three galaxies all lie relatively close to each other in the constellation of Tucana and are interacting gravitationally with one another. The Hubble photo captures the exchange of material between NGC 7733 and NGC 7734, which are on course to merge into a single larger galaxy. As the galaxies grow closer, the gravitational pull of NGC 7734 syphons gas and dust from its smaller companion. "This is actually one of the many challenges that observational astronomers face: working out whether an astronomical object really is just one, or one lying in front of another as seen from Earth's perspective," ESA officials said.

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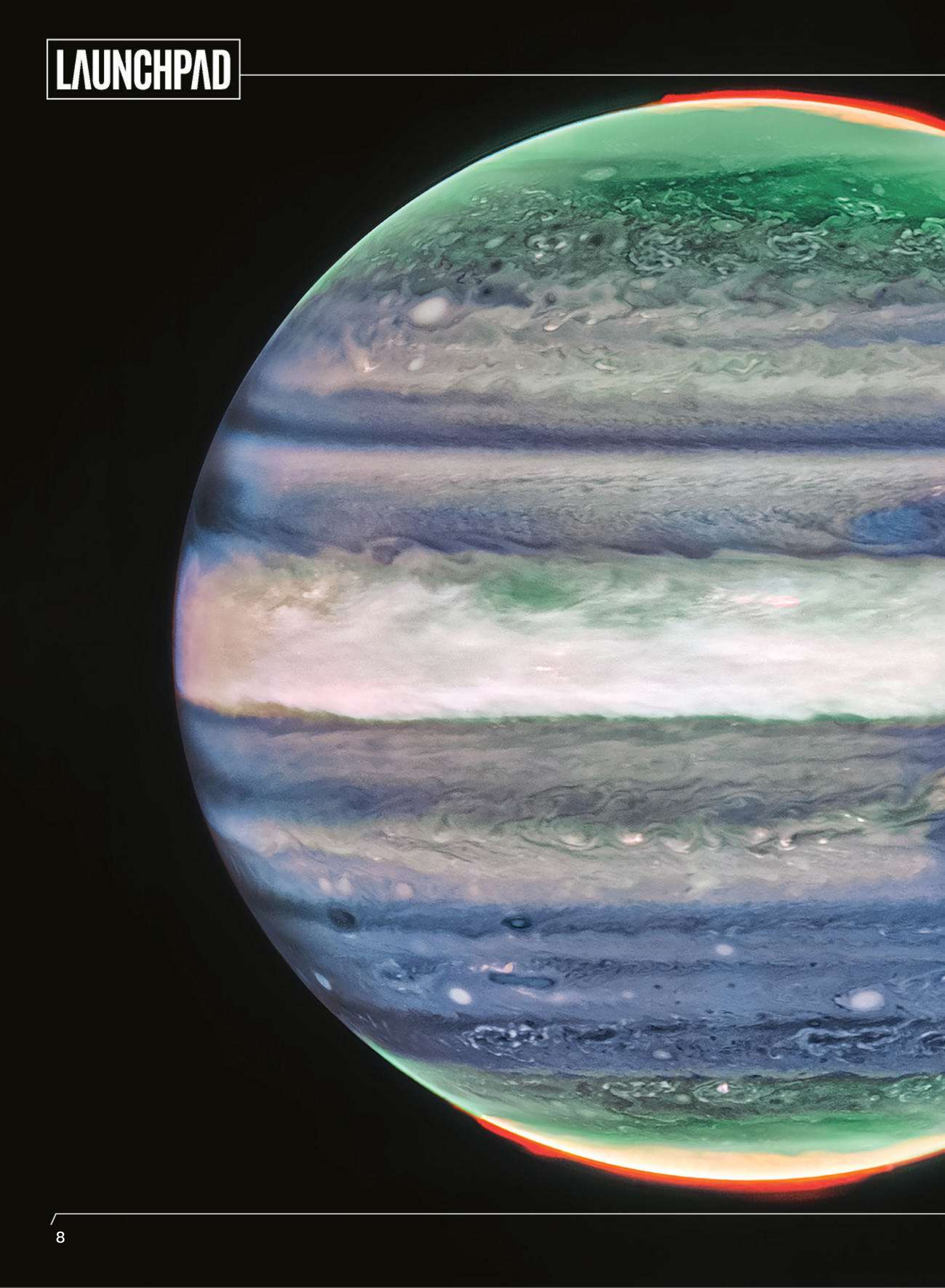

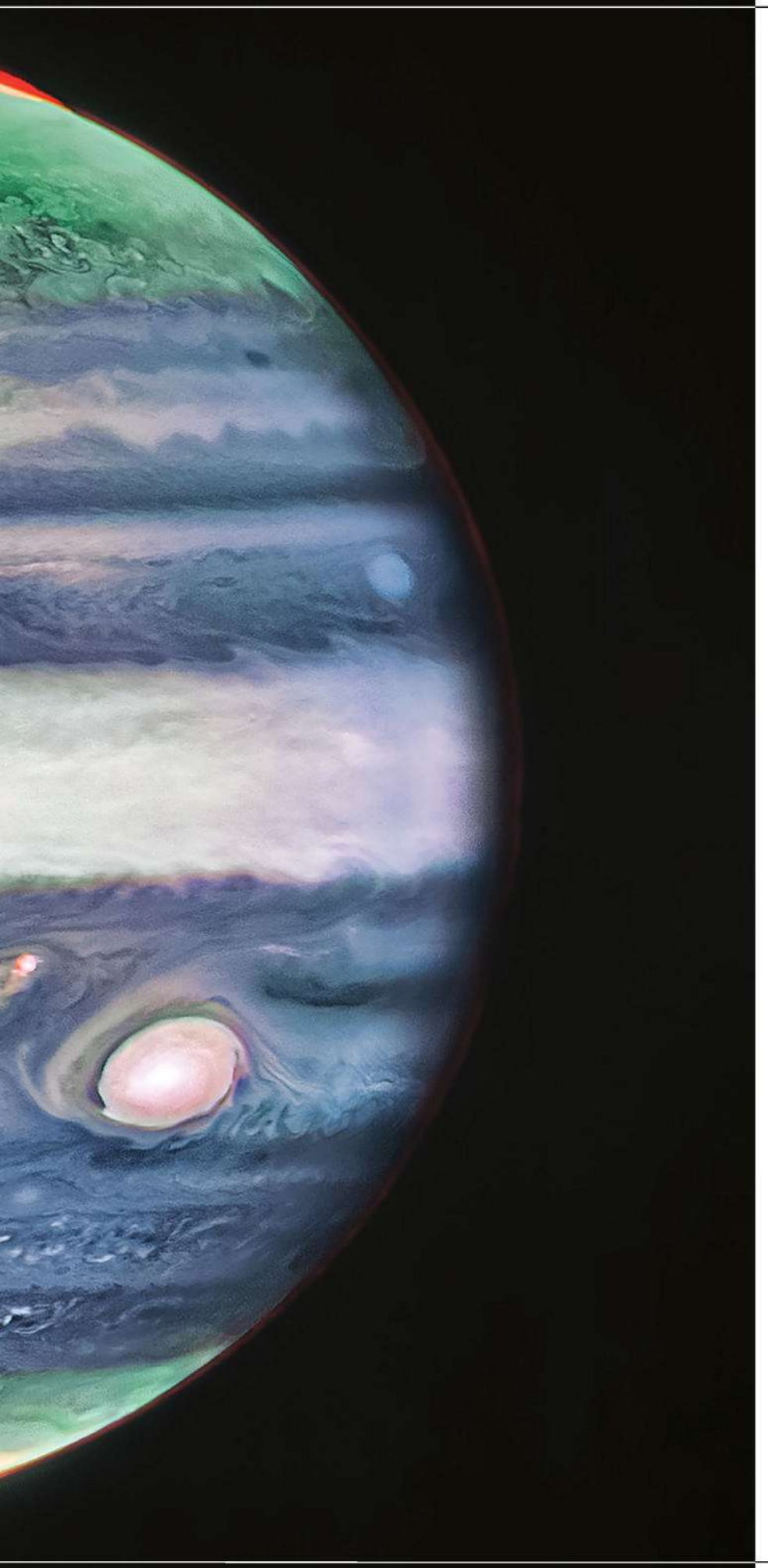

19 October 2023

A jet stream on Jupiter is stronger than a Category 5 hurricane

Though NASA's James Webb Space Telescope was initially touted as having the power to unveil our universe's furthest horizons – and it surely has – some of the observatory's most gorgeous images are actually ones of our very own Solar System. With its gold-plated hive of mirrors and backpack of infrared equipment, such as the Near-Infrared Camera (NIRCam), Webb has reintroduced us to the stunning place we call home, making us feel like we're seeing our planetary neighbours for the first time all over again. It even offered us a poignant view of Neptune's frail rings, something that hasn't been done for 30 years.

On 19 October, scientists announced that, beyond offering us fresh eyes on the Solar System, Webb's images of our cosmic neighbourhood are also presenting us with new data about a planet we thought we knew quite well: Jupiter. Images the observatory took of the gas giant last year have managed to show us brand-new things about its moons, atmosphere and rings. After examining images Webb captured of Jupiter in 2022, a team of researchers realised there's a high-speed jet stream on the planet that's more than 4,800 kilometres (3,000 miles) wide and travelling at about 515 kilometres (320 miles) per hour This is something that has never been seen before. "That totally surprised us," Ricardo Hueso of the University of the Basque Country in Bilbao, Spain, and lead author on a paper describing the findings, said.

"It's amazing to me that after years of tracking Jupiter's clouds and winds from numerous observatories we still have more to learn," Leigh Fletcher of the University of Leicester, a member of the new study, said. According to the team, this newfound jet stream on Jupiter – which is blasting away at about twice the speed of a Category 5 hurricane on Earth and sits right above the equator – might shed some light on the planet's turbulent atmosphere. In fact, all of those 2022 Jupiter images might help researchers deduce what goes on in the skies of the apricot-striped orb. "What we have always seen as blurred hazes in Jupiter's atmosphere now appear as crisp features that we can track along with the planet's fast rotation," Hueso said.

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10 October 2023

Webb spotlights gorgeous young stars next door

A star-studded cosmic neighbour 210,000 light years away is now available to view on our computer screens in unprecedented detail thanks to NASA's mighty James Webb Space Telescope and the power of the modern internet. The newly released Webb photo captures NGC 346, a star-forming region in a satellite galaxy of the Milky Way called the Small Magellanic Cloud (SMC). The blue wisps of light represent emissions from molecules like silicates and polycyclic aromatic hydrocarbons, while red fragments highlight dust warmed by the brightest and most massive stars in the region's centre.

Overall, astronomers have detected 1,001 light dots in the image – and most of them are still young stars blanketed in dust. This pocket of the universe is much younger than the Milky Way, which is seen in the fewer amounts of heavy elements it features. The intriguing region is visible to the unaided eye in the southern constellation of Tucana. Heavy metals are usually churned in stars across time spans of aeons, then deposited back into their local surroundings via cosmic processes like nuclear fusion and supernova explosions. Astronomers know cosmic dust is formed from those heavy elements, so they expected to see little of it in the NGC 346 region. However, the latest photo shows "ample dust within this region," Webb representatives said.

Astronomers say the image, which was captured using the Mid-Infrared Instrument (MIRI) on board Webb, is allowing them to better understand how many stars and protostars are present in the region. Those observations could eventually shed more light on an era in the universe billions of years ago known as cosmic noon. At that time, star births reached a peak rate across the universe and the level of heavy elements was lower than amounts measured today – a distribution in line with how NGC 346 is now evidenced to be.

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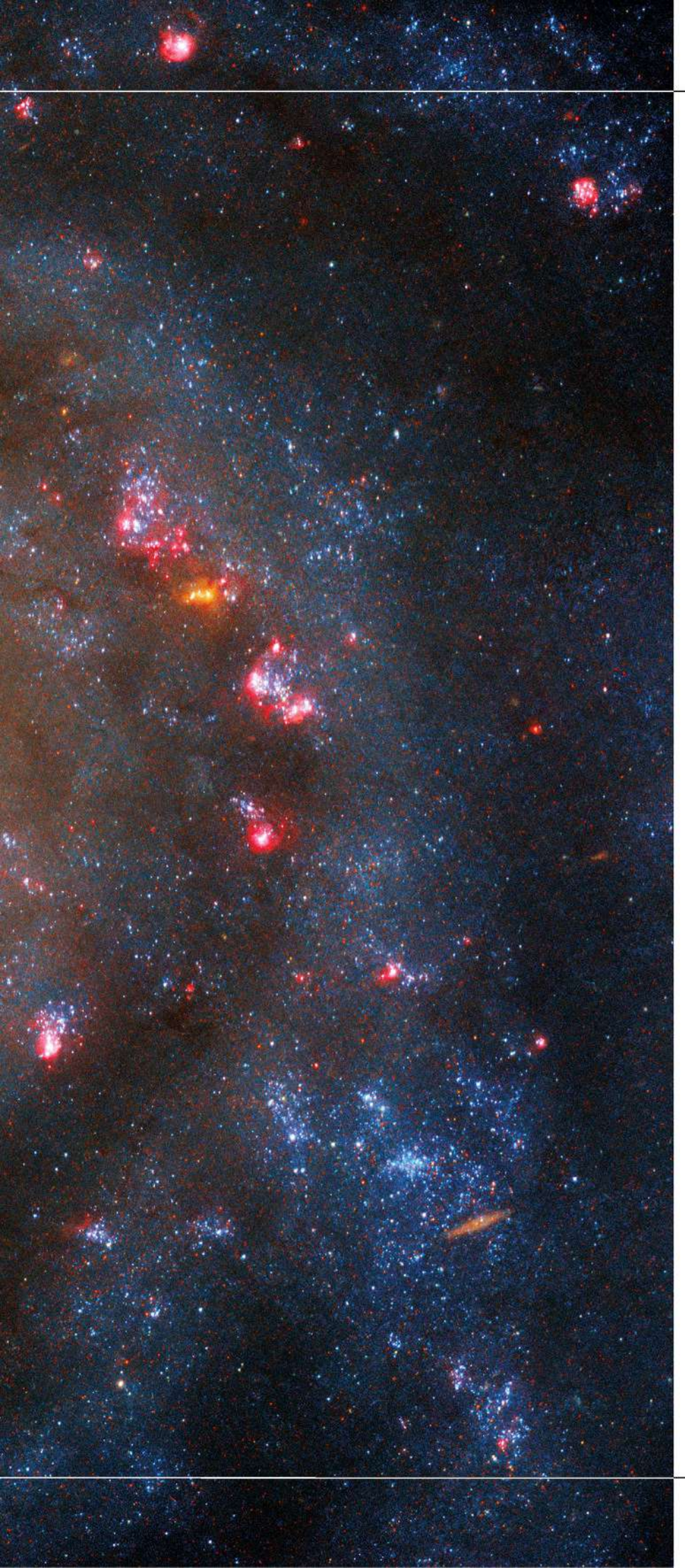

16 October 2023

Hubble captures a striking new face-on galaxy portrait

The Hubble Space Telescope has captured a striking new face-on view of a spiral galaxy with loosely wound arms swirling around a bright core. The spiral galaxy IC 5332 lies approximately 30 million light years from Earth in the constellation of Sculptor. Hubble's vantage point offers a face-on view of the galaxy, showcasing its large circular structure and winding spiral arms dotted with brightly glowing clusters of star formation in pink and orange. "To explain what is meant by 'face-on', it's helpful to visualise a spiral galaxy as an extremely large disc," ESA officials said. "If the galaxy is oriented so that it appears circular and disc-shaped from our perspective here on Earth, then we can say that it's 'face-on'."

Conversely, a galaxy may appear 'edge-on' from our perspective on Earth. In this case, the galaxy would look squashed and oval-shaped, rather than disc-shaped. But given that an edge-on view captures the galaxy from the side – oftentimes revealing a bright central bulge – viewers lose any sight of the galaxy's intricately wound arms from this angle. "The key thing is that the same galaxy would look extremely different from our perspective depending on whether it was face-on or edge-on as seen from Earth," ESA officials said.

IC 5332 is classified as a SABc-type galaxy, meaning it lacks a clear central bar structure and its spiral arms are not very tightly wound. About two-thirds of all spiral galaxies have a distinct, elongated bar-shaped structure at their centre, while others spiral out from one single point – known as an unbarred spiral galaxy. With a weak central bar, IC 5332 falls somewhere in the middle, also known as an intermediate spiral galaxy, which is what the SAB stands for. Although IC 5332 has well-defined arms of bright stars that curl outwards from the galaxy's dense, bright core, its spiral arms are not tightly wound, which is why it's assigned a lowercase 'c' on the classification scale, where 'a' would indicate very tightly wound and 'd' very loosely wound, ESA officials explained.

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The remnants of an alien 'protoplanet' could be hidden deep within Earth

Reported by Charles Q Choi

The newborn Earth was struck by a Mars-sized rock that helped create the Moon, and the impact may have left behind continent-sized remnants of the rock near Earth's core. Scientists think Earth formed about 4.5 billion years ago, and previous research suggested the Moon arose a short time later. The leading explanation for the Moon's origin is that it resulted from the collision of two protoplanets. One of those was the young proto-Earth, and the other was a Mars-sized rock nicknamed Theia, after the mother of the Moon in Greek myth.

This 'giant-impact hypothesis' suggests the Moon coalesced from debris from this impact. However, direct evidence for the existence of Theia remains elusive. Now, researchers suggest this giant impact may have buried relics of Theia deep within Earth's mantle near the planet's core. "Our work indicates this giant impact had a long-lasting effect for Earth's whole evolution, and it could potentially explain why Earth is geologically unique compared to other rocky planets," study lead author Qian Yuan, a geodynamicist at the California Institute of Technology in Pasadena, said.

In a new study, Yuan and his colleagues investigated two continent-sized blobs of rock in the lowermost mantle, about 2,900 kilometres (1,800 miles) below Earth's surface. Previous research found

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seismic waves rippling through Earth's interior travelled unusually slowly through these anomalies. This suggested that they were denser than and differed in composition from the surrounding mantle. The research team's computer simulations revealed that a fraction of Theia's mantle could have made its way to proto-Earth's lower mantle. This rock from Theia would have been 2.0 to 3.5 per cent denser than proto-Earth's mantle based on what is known from the Moon and previous models of Theia.

The computer models suggested these dense Theia relics were tens of miles wide. This mostly molten rock could have sunk and solidified over time, accumulating as dense blobs on top of Earth's core equal in weight to about one-40th to one-60th of Earth's mass. These new findings suggest these blobs would be more iron-rich than Earth's normal mantle rock, Yuan said. They could be similar in chemistry to lunar volcanic rock, he added.

Traces of these blobs could make their way to Earth's surface with the aid of mantle plumes, giant, mushroom-shaped pillars of super-heated rock that rise up from near Earth's core. Prior work suggested that Iceland and the island chains of Hawaii and the Galápagos formed as tectonic plates slowly drifted over mantle plumes, which seared overlying material like a blowtorch. "Some traces of the Theia relics could be brought to surface volcanoes by mantle plumes," Yuan said.

Yuan is now investigating whether this pair of blobs may have helped spur on geological activity unique to Earth. Our planet's surface is made of massive tectonic plates, and the way in which these slabs drift, known as plate tectonics, drives earthquakes and volcanoes, creates mountain ranges and islands and liberates vital elements from rocks. The strongest driving force behind plate tectonics is subduction – when one plate dives under another – and Earth is so far the only planet where subduction is known to occur. Yuan aims to see if these two blobs in the deep mantle could help drive subduction.

< Artwork of the young Earth-Moon system. Earth had recently formed when it was struck by a protoplanet called Theia, roughly three times the size of Mars

The Chicxulub asteroid created a two-year cloud of dust that may have killed the dinosaurs

Reported by Sharmila Kuthunur

Some 66 million years ago, a large asteroid crashed into Earth near Mexico's Yucatán Peninsula, sparking a frigid global winter that led to the mass extinction of the dinosaurs who had reigned over the planet for over 160 million years. Scientists generally agree that the Chicxulub impact wiped out 75 per cent of all species on Earth, but precisely what caused the extreme and abrupt shift in climate following the event has been an open question. Now, new research pins it down to very fine dust particles that were blasted into the atmosphere due to the impact. A layer of dust blanketed Earth for up to 20 years, "in which the first five to eight years are the most severe," Cem Berk Senel, a postdoctoral researcher in planetary science at the Royal Observatory of Belgium, and his team wrote in a new study. In the first year after the impact, global temperatures dropped by more than ten degrees Celsius (18 degrees Fahrenheit).

A 66-million-year-old rock sample Senel and his team collected in North Dakota, about 3,000 kilometres (1,800 miles) north of the Chicxulub crater, shows more fine dust particles than expected, suggesting dust played a bigger role in the cataclysmic event than thought. The change in Earth's history from what geoscientists call the Cretaceous period to the Palaeogene period is recorded in a 1.3-metre (4.3-foot) part of the collected rock, which formed at the time of the Chicxulub event. After measuring the sizes of particles in this section of rock, Senel and his team used the data to simulate a post-impact climate. The simulation predicted a blanket of dust particles between 0.8 and 8.0 micrometres in diameter formed just a week after impact. Within two weeks that blanket, which researchers suspect hovered in Earth's atmosphere longer than soot and sulphur, stopped plants from photosynthesising for up to two years. The shutdown starved species relying on them, including non-avian dinosaurs.

v An artist's illustration of the asteroid impact that killed the dinosaurs

Swirling gas helps scientists nail down the Milky Way's supermassive black hole's mass

Reported by Connor Feehly

At the centre of our galaxy sits a dark enigma, a supermassive black hole named Sagittarius A* (Sgr A*). Now, according to new findings from the Max Planck Institute for Extraterrestrial Physics, a group of astronomers has determined with high accuracy the mass and radius of Sgr A*. Specifically, Sgr A* was found to come in at a whooping 4.297 million solar masses, with a radius smaller than that of Venus' orbit around the Sun. The team deduced this information by studying the luminous gas found in this enormous void's orbit.

The researchers used data from the near-infrared interferometer at the European Southern Observatory's Very Large Telescope Interferometer (VLTI) to track electromagnetic emissions of gas swirling around the black hole. They were on the lookout for flares – bright flashes of electromagnetic radiation that might happen once or twice a day. These flares allowed the astronomers to trace the motion of gas surrounding Sgr A*. The team analysed flares observed in 2018, 2021 and 2022. This combined data allowed the researchers to estimate the mass of the black hole with a high level of accuracy. The gravitational radii of Sgr A* was found to be equal to roughly 0.1 astronomical units, or one-tenth the distance from Earth to the Sun. While this might sound small, it's actually relatively large, as the Sun's gravitational radii value is equal to approximately three kilometres (1.9 miles). This is also the size the Sun would need to be compressed to before it could collapse into a black hole.

An artist's impression of the Milky Way

China's Shenzhou 16 astronauts may have landed with a ripped parachute

Reported by Andrew Jones

China's Shenzhou 16 astronauts landed safely on Earth despite an apparent hole appearing in their return capsule's parachute. China Central Television aired video of the descent of Shenzhou 16 as the crewed spacecraft returned to Earth following five months in orbit docked with the Tiangong space station. Inside the capsule were Shenzhou 16 mission commander Jing Haipeng and crewmates Zhu Yangzhu and Gui Haichao – the latter pair returning to Earth after their first mission to space. Such a sizable hole, which was visible before a white cloud of vented propellant left the Shenzhou capsule, had not been reported during earlier missions. However, it did not seem to affect operations.

The capsule touched down safely at the Dongfeng landing site in the Gobi Desert in Inner Mongolia at 00:11 UTC, or 08:11 Beijing time, on 31 October. When it did land, the capsule appeared to tumble a couple of times before being enveloped in a cloud of sand kicked up by the impact, which Shenzhou capsules soften by firing thrusters. Even if the 1,200-square-metre (12,920-square-foot) parachute had failed, the crew would still have had another opportunity to slow their descent. Shenzhou spacecraft carry a backup parachute should the main chute fail.

China's Shenzhou 16 descended through Earth's atmosphere on 31 October. An apparent hole is visible in the chute, to the lower left of the circle at its centre

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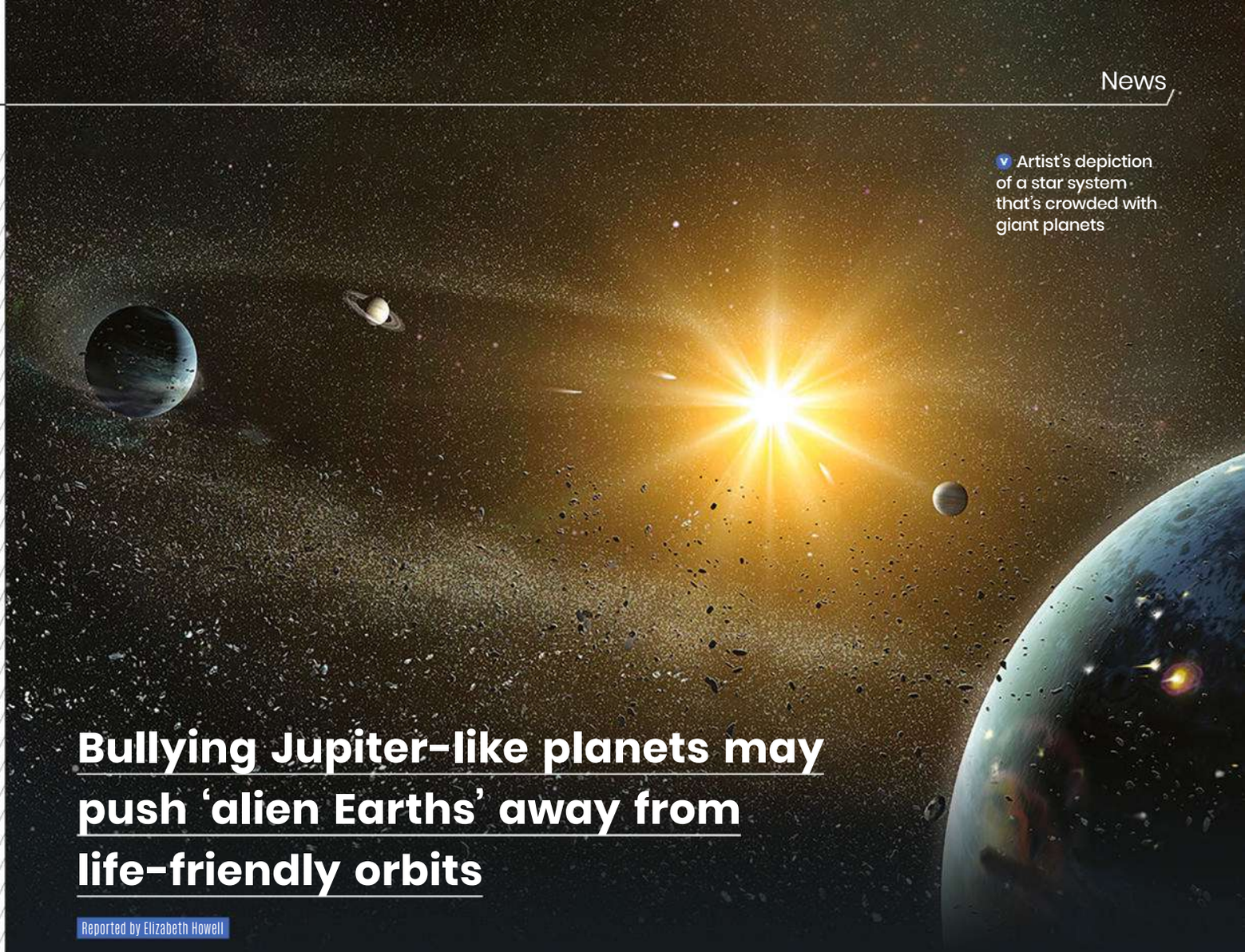

Artist's depiction of a star system that's crowded with giant planets

Bullying Jupiter-like planets may push 'alien Earths' away from life-friendly orbits

Reported by Elizabeth Howell

Like huge playground bullies, planets like Jupiter can be agents of chaos around other stars, a pair of new studies suggests. Gas giant planets that are the size of Jupiter or larger create havoc in young planetary systems, often shoving smaller, Earth-sized planets way out of their original circular orbits. All this instability spells bad news for life on terrestrial planets, as organisms need stable conditions to take root and flourish. Just watch the 2011 film *Melancholia* to get the idea: a planet – once hit by or veering too close to a neighbour – will see its climate permanently destabilise.

Take the nightmare scenario of four giant planets that orbit a star known as HD 141399. "It's as if they have four Jupiters acting like wrecking balls, throwing everything out of whack," Stephen Kane, an astrophysicist at the University of California, Riverside, who authored one of the new studies, said. While the quartet is relatively far from their star, their presence would still be bad news for an Earth-like planet in the habitable zone – the approximate orbital range where liquid water would be feasible on a terrestrial world's surface. Computer simulations showed that Earth would have a tough time staying viable with so many big planets nearby. "It's very unlikely," said Kane. "There are only a select few areas where the giants' gravitational pull would not knock a rocky planet out of its orbit and send it flying right out of the zone."

Luckily, Earth doesn't have that kind of *Hunger Games* energy to worry about. In fact, Jupiter's presence in our neighbourhood is a boon. The gas giant's strong gravity acts more like a shield, bouncing away comets or asteroids that would otherwise beeline for our little world. But if Jupiter were in the middle of our habitable zone, our Solar System might be a very different place. A star just 30 light years away from Earth, called Gliese 357, was scrutinised in a second related study. By comparison, Alpha Centauri – the closest planetary system to us – is roughly four light years away.

New estimates of a habitable zone planet known as Gliese 357 d show that it's perhaps ten times more massive than Earth, nearly double the previous estimate. Such a heavyweight would likely prevent Earth-size planets from safely sailing nearby, unless the smaller planet's orbit was highly elliptical – meaning that the world careens close to and then zings far away from its parent star on its pathway in space. "In other words, the orbits would produce crazy climates on those planets," said Kane, who co-authored the second study with visiting assistant professor at California State University, San Marcos, Tara Fetherolf. "This paper is really a warning, when we find planets in the habitable zone, not to assume they are automatically capable of hosting life." Both of these planetary systems show what could have happened to us if we had too many Jupiters in our neighbourhood, or a single Jupiter that came too close. "Our work gives us more reasons to be very grateful for the particular planetary configuration we have in our Solar System," Kane said.

A view of the Moon as seen by the uncrewed Orion spacecraft during Artemis I in December 2022

A new water system that could aid Artemis astronauts gets tested on the ISS

Reported by Elizabeth Howell

A new water-dispensing system on the International Space Station (ISS) aims to test out technology that could help future astronauts explore the Moon. The roomy ISS is described by NASA officials as being larger than a six-bedroom house. Astronauts flying to the Moon in the coming decade with NASA's Artemis program will not have nearly as much room in the Orion spacecraft, in lunar landing vehicles or in NASA's smaller Gateway space station planned for lunar orbit.

Everything will need to shrink for Artemis lunar work, including food preparation stations, exercise equipment and medical kits. Towards this end, a new potable water dispenser built by the company Leidos flew to space aboard Northrop Grumman's Cygnus cargo spacecraft on 1 August as part upgrade, part lunar technology demonstration. A previous generation of US water dispensers was delivered to the ISS in 2008 and remains functional.

The new design "tackled some of the more significant Artemis mission challenges, including longer duration water stagnation periods and reducing limited life items," said Deborah Wells, division manager at Leidos. Leidos works in fields including civil, defence, health and intelligence; in the field of space exploration, the company says it has been working for 50 years in information technology, engineering and science.
With the addition of the new dispenser, ISS astronauts now have at least three locations where they can find drinkable water: in the Russian Zvezda module, in the US Unity node and now in the US Destiny module.

There are numerous upgrades from previous generations of water dispensers, Wells emphasised. The heater portion has less power draw due to better optimisation for water heating needs. The system can also send back telemetry to Mission Control, where ground personnel can tweak the settings if needed, reducing astronaut maintenance time in space. Both features will be essential on Moon missions, where power and time will be more limited.

The system is also designed to remove 'biocide' – a treatment that addresses microbes – in the water, and to disinfect water using ultraviolet rays. Both treatments are especially important, as the dispenser hooks into NASA's urine-recycling system. Very simply put, NASA's Environmental Control and Life Support System aboard the ISS uses a urine processor assembly. The assembly safely recovers drinkable water from urine using vacuum distillation, and recently achieved a remarkable 98 per cent water recovery rate.

This urine-recycling innovation will also be useful for the exploration of deep space, where shipping water from Earth is less feasible. The milestone also means that even in locations where water may be recovered from the surface, such as the Moon, future astronauts will have less need to draw on the precious resource for interplanetary living.

"Leidos also completed major updates to the plumbing architecture and design," Wells said of the new dispenser, saying the new design has a more simple plumbing system that removes 'dead legs', or water stagnation points. These dead legs are difficult for crews to access and disinfect, but such measures were needed periodically, as biofilms and microbiological growth tend to collect in the legs. The new design "eliminated those dead legs and optimised fluid flow to help eliminate areas where biofilms and microbes could take hold," Wells said.

The new ISS water dispenser is not an exact duplicate of the version that would aid Artemis. But Wells said the Moon design will borrow from the architecture, plumbing layout and components used in low-Earth orbit. It's meant to help astronauts with the longer surface excursions envisioned for the later 2020s and beyond; earlier Orion spacecraft, such as the capsule that will fly on Artemis II, which will send astronauts around the Moon in late 2024, already have dispensing systems ready to go. "A system such as this will be needed to support Artemis missions and NASA's Moon-to-Mars architecture," Wells said, referring to the hardware NASA plans to use for future deep space-missions. "The demonstration of this technology on the ISS helps validate its improvements and identify changes that would enhance those future systems."

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From black holes to neutron stars, tiny moons to massive planets and violent outbursts to matter that defies light, our knowledge of space has burgeoned since the 1600s, with what follows merely the tip of the iceberg in that outstanding voyage of discovery

Written by Robert Lea

SUPPLIED BY NASA **[N]**, the European Space Agency **[ESA]**, European Southern Observatory **[ESO]**, All About Space **[AAS]**, National Science Foundation's NOIRLab **[NOIR]**, Universidad Nacional de Colombia **[UNC]**, Princeton University **[PU]**, International Gemini Observatory **[IGO]**, University of Sussex **[UoS]**, Event Horizon Telescope **[EHT]**, Northwestern University **[NU]**, Indian Space Research Organisation **[ISRO]**, Caltech **[C]** Instituto de Astrofísica de Canarias **[IAC]**, LIGO **[L]**, International Astronomical Union **[IAU]**, Cardiff University **[CU]**, Sodankylä Geophysical Observatory **[SGO]**, University of Oxford **[UoO]**, North American Nanohertz Observatory for Gravitational Waves **[NANO]**, Sussex University **[SU]**

150 THE UNIVERSE IS STILL MYSTERIOUS

NOIR Scientists determined the energy and matter content of the universe, discovering that the 'everyday matter' made of atoms – themselves composed of protons and neutrons – accounts for just five per cent of the 'stuff' in the cosmos. That means everything we see on a day-to-day basis is just a drop in the cosmic ocean, with the rest composed of dark matter, accounting for around 25 per cent, and dark energy, accounting for a whopping 70 per cent.

Despite all of our advancements and discoveries in the name of science, we still have no idea what 95 per cent of the universe is. One of the reasons this is so important to know is that dark energy pushes galaxies apart on a large scale, almost like an 'antigravity', while dark matter seems to act to hold them together both internally and in galactic clusters. Understanding this cosmic tug-of-war is key to knowing how the universe will continue to evolve, how it will eventually end and if this could be a 'Big Rip' scenario in which the fabric of space-time itself shreds.

AAS

149

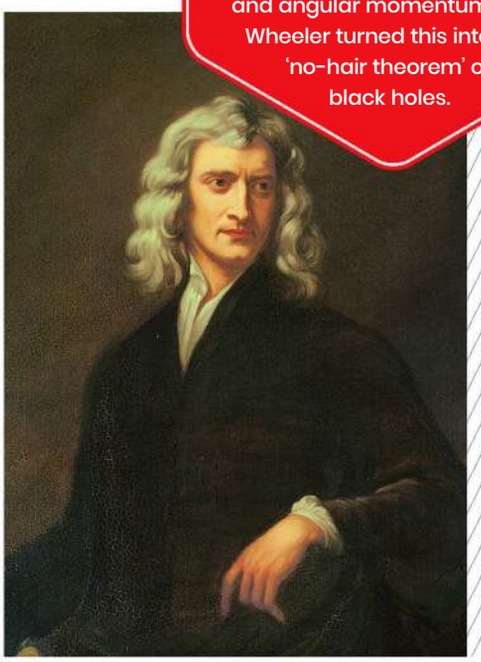
BALD BLACK HOLES

In 1967, Werner Israel theorised that black holes are simple and can be described by three characteristics: mass, charge and angular momentum. John Wheeler turned this into his 'no-hair theorem' of black holes.

148

NEWTON'S LAWS OF GRAVITY

N Formulated by Isaac Newton in 1687, Newton's law of gravitation revolves around the statement that any particle of matter in the universe attracts any other with a force, the strength of which varies as a product of their masses and inversely varies as the square of the distance between the masses increases. Though Einstein expanded on this and showed that gravity isn't a force, without this development, many of the discoveries listed here wouldn't have been possible. Unfortunately, the story of Newton being inspired by an apple falling on his head is very likely apocryphal.



147

PUSH IT TO THE LIMIT

AAS Subrahmanyan Chandrasekhar calculated the dividing line between a star that can go supernova and one that can't, determining that a star would need 1.4 times the mass of the Sun when it runs out of fuel to explode and leave a supernova in its wake. This is the Chandrasekhar limit.

146

THE SUN WILL NEVER GO SUPERNOVA

AAS One consequence of the Chandrasekhar limit is that astronomers can be pretty sure that our star, the Sun, will never go supernova. That means our star will end its life as a smouldering white dwarf – a stellar remnant.

145

THE FIRST WHITE DWARF DISCOVERY

AAS The first example of a white dwarf star was discovered on 31 January 1783 by William Herschel. The white dwarf 40 Eridani B is part of a three-star system with a second white dwarf, discovered in 1862.

144

VAMPIRE WHITE DWARFS BLOW THEIR TOPS

AAS A white dwarf star may be the end stage for the Sun, but some dead stars can spring back to life if they are feeding on material from a companion star, eventually erupting in a Type Ia supernova explosion.

143

LET THERE BE LIGHT

AAS In 1672, Newton separated white light into its constituent wavelengths, discovering that colours are the result of variations in wavelength and frequency. This breakthrough became vital in understanding the composition of stars and planetary atmospheres via a technique called spectrometry.

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142

THE BIRTH OF A GAS GIANT

NASA The realisation that Jupiter is composed of mainly gas can be traced back to 1690, when Italian astronomer Giovanni Domenico Cassini first noticed that the atmosphere of the planet undergoes differential rotation – different zones across the planet rotate at different speeds – suggesting it isn't a solid body. Between 1932 and 1955, scientist W. R. Ramsey began theorising that because of its low density, Jupiter may be a giant body consisting mainly of hydrogen gas, which becomes metallic at high pressures and high temperatures. This suggested that not all planets in the Solar System, and eventually beyond, are rocky like Earth.

ESA

141

LIFE CYCLE OF A STAR

The Hertzsprung-Russell diagram charting the relationships between various stellar characteristics began to take shape in 1911 as astronomers began to realise that some of the variety they see between stars is the result of viewing them in the different stages of their evolution.

140 BEST OF BOTH WORLDS

NU A gravitational wave breakthrough came in August 2017 when astronomers made the first and only detection of both gravitational waves and light from an event – the merger of neutron stars 130 million light years away. "The coincident discovery of gravitational and electromagnetic radiation from the merger of two neutron stars impacted numerous fields in astronomy," Northwestern University scientist Jillian Rastinejad tells **All About Space**. "This event provided a new path to testing the rate of the expansion of the universe, identified the previously unknown origin of many of the heavy elements and confirmed the long-held hypothesis that neutron star mergers produce short gamma-ray bursts."

139

FAST RADIO BURST DETECTED

ESA The first fast radio burst, a rapid blast of radio waves lasting between seconds and microseconds, was found by Duncan Lorimer in archival data in 2007. It's officially called FRB 010724, but is less formally known as the Lorimer Burst.

138

FAST RADIO BURSTS REPEAT

ESA In 2012, astronomers discovered that one of these bursts of radio waves wasn't a one-off – it repeated. The discovery of FRB 121102 complicated the search for fast radio burst sources, suggesting astronomers had to find two causes, not one.

137

A CLUSTER OF REPEATING FAST RADIO BURSTS

ESA In April 2023, astronomers doubled the number of known repeating fast radio bursts from 25 to 50 using the Canadian Hydrogen Intensity Mapping Experiment, hinting that many single-burst fast radio bursts may be repeaters if we watch them long enough.

136

SPACE HAS A TEMPERATURE

ESA Thanks to the discovery of the cosmic microwave background, scientists know that even in the emptiest regions of space, the temperature is 270.5 degrees Celsius (519 degrees Fahrenheit), or a few degrees above absolute zero – the coldest possible temperature, at which molecular movement stops.

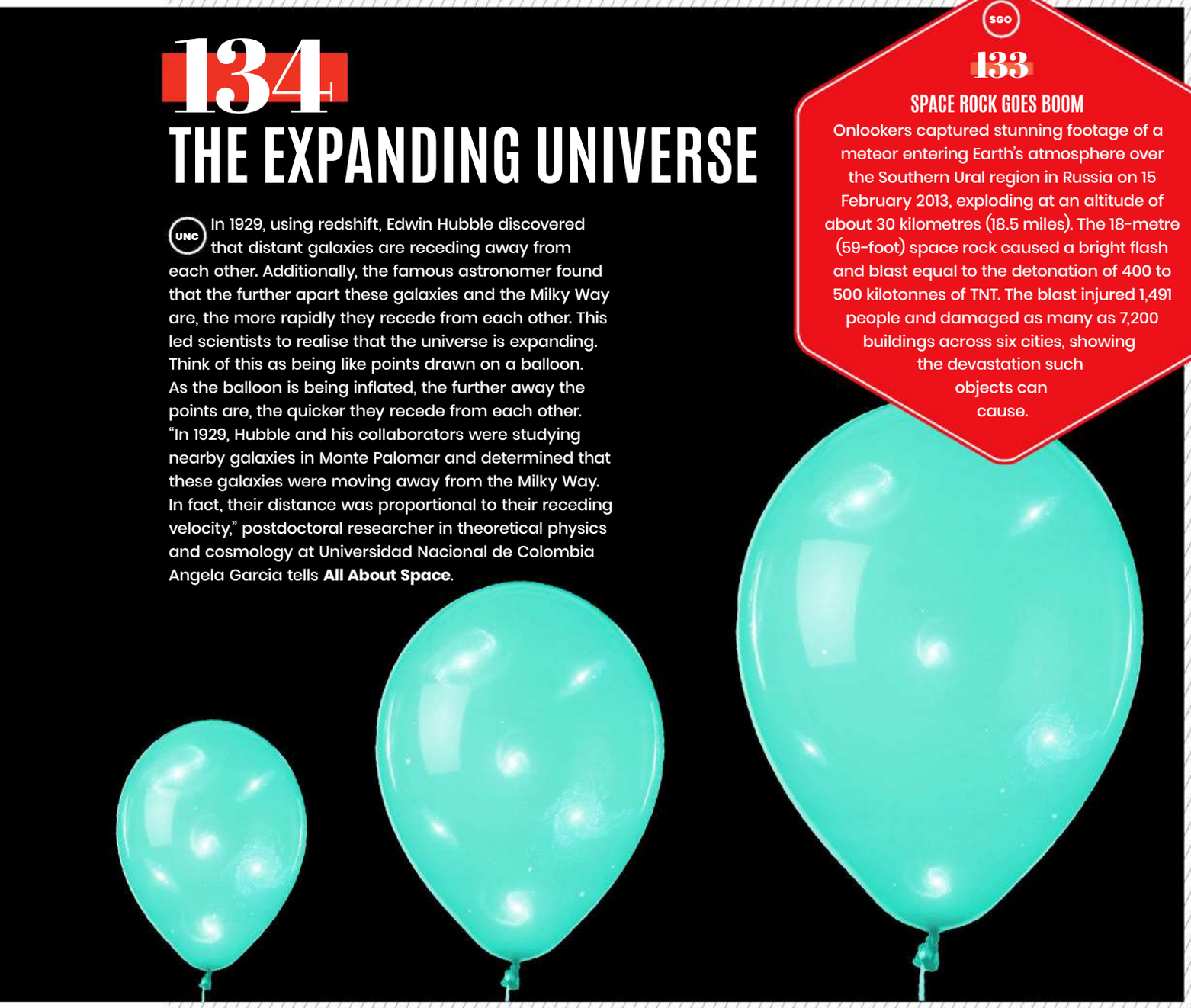
135

BUT SOME PARTS ARE COLDER...

ESA In the 1980s, Australian astronomers discovered the Boomerang Nebula. It's the coldest object in the universe with a temperature of around -272 degrees Celsius (-521.6 degrees Fahrenheit), or just above absolute zero.

134 THE EXPANDING UNIVERSE

UNC In 1929, using redshift, Edwin Hubble discovered that distant galaxies are receding away from each other. Additionally, the famous astronomer found that the further apart these galaxies and the Milky Way are, the more rapidly they recede from each other. This led scientists to realise that the universe is expanding. Think of this as being like points drawn on a balloon. As the balloon is being inflated, the further away the points are, the quicker they recede from each other. "In 1929, Hubble and his collaborators were studying nearby galaxies in Monte Palomar and determined that these galaxies were moving away from the Milky Way. In fact, their distance was proportional to their receding velocity," postdoctoral researcher in theoretical physics and cosmology at Universidad Nacional de Colombia Angela Garcia tells **All About Space**.



SGO

133 SPACE ROCK GOES BOOM

Onlookers captured stunning footage of a meteor entering Earth's atmosphere over the Southern Ural region in Russia on 15 February 2013, exploding at an altitude of about 30 kilometres (18.5 miles). The 18-metre (59-foot) space rock caused a bright flash and blast equal to the detonation of 400 to 500 kilotonnes of TNT. The blast injured 1,491 people and damaged as many as 7,200 buildings across six cities, showing the devastation such objects can cause.

132 EARTH ISN'T FLAT

NASA In the 3rd century BCE, protoscientists calculated the shape of the Earth, determining that it is a sphere. This has now been proven.

131 A HISTORY OF EXTINCTION

NASA Via fossil records, scientists found our planet has a long and rich living history; most of the creatures that preceded us are gone, some wiped out in disastrous extinction events.

130 AN ASTEROID KILLED THE DINOSAURS

NASA In 1825, scientists discovered that the dinosaurs died out suddenly with three-quarters of life on Earth. It was soon theorised this was the result of an asteroid – the Chicxulub impactor.

129 THE SOLAR SYSTEM'S VIOLENT PAST

NASA In the 1960s, scientists realised asteroid impacts on Earth and other planets were more frequent around 4 billion years ago during the Late Bombardment Period.

128 THE FIRST CELESTIAL CATALOGUE

NASA In 1774, Charles Messier created a prototype version of his catalogue of deep-sky objects that became the Messier catalogue, with many galaxies still bearing the prefix 'Messier'.

127 COLD VOLCANOES

AAS In 2010, scientists discovered that Saturn's moon Titan has volcanoes that spray ice instead of lava, showing the real variety of conditions in the Solar System, even among its many moons.

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126

BLACK HOLES AREN'T JUST THEORY ANY MORE

AAS After springing forth from Einstein's theory of general relativity, black holes remained purely theoretical until scientists spotted Cygnus X-1 in 1971, which was confirmed to be a stellar-mass black hole in 1990.

125

SUPERMASSIVE

AAS Black holes display a vast disparity in mass. The first stellar-mass black hole ever found has 15 solar masses, but the black hole at the heart of Messier 87 was found to be billions of solar masses. The classification of supermassive black holes was born.

124

BLACK HOLES ARE MESSY EATERS

AAS The discovery of the gargantuan black hole at the heart of Messier 87 also showed that some black holes voraciously consume the matter around them, leaving wreckage that can be blasted out in near-light-speed jets emitting powerful radiation, classed as active galactic nuclei called quasars.

123

THE VAN ALLEN BELTS

NASA Scientist James Van Allen and his team at the University of Iowa discovered that Earth is surrounded by radiation belts, now called the Van Allen belts – a vital zone in human space exploration.

122

SOMETHING'S MISSING IN OUR RECIPE OF THE UNIVERSE

ESA In 1933, Swiss astrophysicist Fritz Zwicky built on the work of others to determine that some matter is missing in our recipe of galaxies – he termed this dunkle Materie, or dark matter.

121

THE MOON'S VIOLENT BIRTH

NASA First suggested by George Darwin in 1898, the giant-impact theory is the idea that the Moon was formed when the infant Earth was smashed by a Mars-sized planet called Theia. The massive spray of material blasted away from Earth by this massive collision eventually cooled and reformed as a single body – the Moon. This theory is supported by the chemical analysis of Moon rocks returned by Apollo 11 in 1969, which showed the Moon has a similar chemical composition to Earth. Though this is currently the most widely accepted theory of how the Moon was born, there are other ideas, such as 'fission theory'. This suggests that Earth once spun so fast it flung away molten material that would later form the Moon.

NASA

120

THE CORONAL HEATING MYSTERY

Bengt Edlén realised that the corona – the outer atmosphere of the Sun – is hundreds to thousands of times hotter than the underlying photosphere, despite being further away from the Sun's core. The outer layer has an estimated temperature of about 1 million degrees Celsius (2 million degrees Fahrenheit).

119

THE SHAPE OF THE MILKY WAY

ESA In 1785, William Herschel attempted to determine the shape of our galaxy, and the famous spiral arms of our galaxy began to resolve themselves. The spiral shape of the Milky Way was confirmed by the Spitzer Space Telescope in 2005 after astronomers analysed over 400 hours of observational data. The Milky Way is now theorised to be a barred-spiral galaxy around 105,700 light years across with two main spiral arms – the Scutum-Centaurus and Perseus arms – that both extended out from a thick, rotating central bar at the heart of the Milky Way. Our galaxy also possesses two less distinct arms, Norma and Sagittarius.

118
SOLAR CYCLE
AAS German amateur astronomer Heinrich Schwabe observed the Sun between 1826 and 1843, watching sunspot activity change. From this he determined the 11.5-year solar cycle.

117
FLARING UP
AAS In 1859, Richard C. Carrington and Richard Hodgson simultaneously observed solar flares for the first time when they witnessed a flash of white light while observing sunspots.

116
DARK SPOTS ACROSS THE MOON
AAS NASA's Lunar Reconnaissance Orbiter revealed details of deep, dark craters called permanently shadowed regions on the Moon in 2013 that never see light.

115
AS THE WORLD TURNS
NASA Though it was known since the days of Galileo, in 1851, Léon Foucault became the first person to experimentally demonstrate that Earth turns on its axis.

114
NUCLEAR FUSION AT THE HEART OF THE SUN
NASA In the 1920s, Arthur Eddington suggested that the source of the Sun's energy is the fusion of hydrogen to helium at its core.

113
COSMIC LIGHTHOUSE
NASA Scientists discovered that pulsing stars that dim and brighten are spinning neutron stars that can rotate as fast as 700 times per second.

ESA
112
TRULY SUPERMASSIVE
One striking example of a black hole, Tonantzintla 618, was first spotted in 1957, but its nature was unknown. We now know it to have a mass of around 40.7 billion solar masses, making it the most massive black hole ever seen to this day.

111
YOU ARE STAR STUFF

ESA The matter that makes up your body comes from dying stars that scattered the material they had forged during their lifetimes. The origin of our understanding of this can be traced back to Fred Hoyle, who, between 1946 and 1954, argued that stars would at their cores perform nuclear fusion to create elements ranging from carbon to iron in mass. When element-forging stars reach the ends of their fuel reserves and can no longer support themselves against the inner push of their own gravity, their cores collapse, while their outer layers are ripped apart in supernova explosions. These cosmic blasts scatter the elements that stars have synthesised over billions of years, and they are eventually incorporated into cosmic dust clouds that collapse to form the next generation of stars and their planets. And, of course, those elements are also incorporated into any living thing that may evolve on those planets. One of the most staggering things about this is that the atoms in your body likely didn't come from the same exploding star. The stars that died to give you carbon, nitrogen and oxygen may have been separated by millions of light years, and those atoms may come together just once to make you.

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110

THE MOST FAMOUS COMET

NASA The first periodic comet, and arguably the most famous comet of all, Halley's Comet, was discovered in 1758 by English astronomer Edmond Halley.

109

AND TRACKED...

NASA Halley's Comet was tracked back to observations over two millennia, with the comet even believed to be featured in the Bayeux Tapestry, a record of the Battle of Hastings of 1066.

108

STUDIED IN DEPTH

NASA Halley's Comet returned to Earth in 1986, with humanity making stunning observations of the comet with an array of telescopes and spacecraft, including NASA's Pioneer 7 and Pioneer 12.

107

GOING ROGUE

ESA Challenging our picture of planets neatly orbiting their stars, in 2012 astronomers discovered an exoplanet called CFBDSIR2149-0403 that wanders the Milky Way alone – the first rogue planet.

106

ROGUES' GALLERY

ESA In 2021, astronomers discovered a huge family of 70 rogue planets wandering the Milky Way. This is the single largest clutch of rogue exoplanets ever seen and suggests there could be many more out there.

105

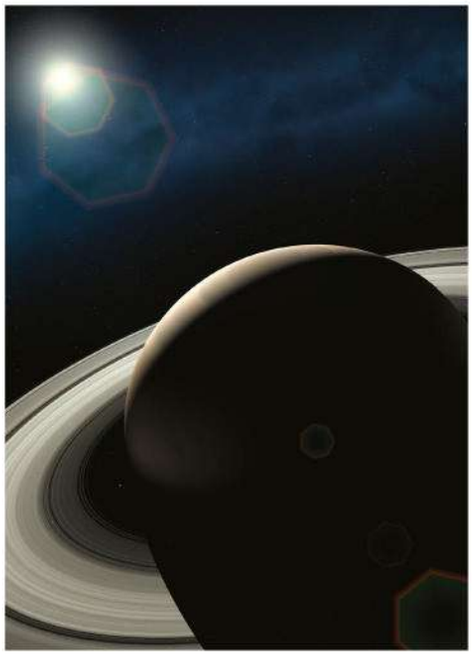
THE MONSTER AT THE HEART OF THE MILKY WAY

ESA On 13 February 1974, a point-like source of intense radio waves was found at the heart of the Milky Way, named Sagittarius A* (Sgr A*). Reinhard Genzel and Andrea Ghez proved that Sgr A* is a supermassive compact object.

104

GALILEO DISCOVERS SATURN'S RINGS

CU Galileo discovered Saturn's rings in 1610, revealing one of the most extraordinary planetary features in the Solar System. The rings of Saturn are made of at least seven distance bands, which themselves consist of tiny chunks of rock and ice coated with dust. It's believed they were created when the tremendous gravity of the gas giant captured and tore apart comets, asteroids and even pieces of shattered moons. Ring systems were later discovered around the other giant planets of the Solar System – Jupiter, Uranus and Neptune, but the rings of Saturn remain the largest and most prominent ring system of the Solar System.



103

DARK MATTER IS THE MISSING INGREDIENT

UoO In the 1970s, Vera C. Rubin and W. Kent Ford saw the stars visible within a typical galaxy only provide around ten per cent of the gravitational 'sticking power' needed to keep those galaxies from flying apart. They did this by measuring the rotational speed of galaxies and determining that they rotate so fast that the gravity of the visible matter within them wouldn't hold them together. There must be a 'hidden' mass that emits or absorbs no light, and thus can't be composed of 'ordinary' atoms. Dark matter was born, and our universe became much more mysterious.

102 VENUS IS HELL

ESA While it is often called 'Earth's twin', the second planet from the Sun is also the hottest place in the Solar System. Similar in size and structure to Earth but spinning in the opposite direction to our planet, the atmosphere of Venus traps heat and causes a runaway greenhouse effect. This drives temperatures at the surface as high as 464 degrees Celsius (867 degrees Fahrenheit), hot enough to melt lead. Additionally, the air pressure at the surface of Venus is estimated to be 75 to 100 times greater than that on Earth. As if this isn't enough, Venus' upper atmosphere is blanketed by thick clouds of sulphuric acid.

"The atmosphere of Venus traps heat and causes a runaway greenhouse effect"

AAS

101 THE MOON'S COMPOSITION

Analysing the lunar surface, scientists discovered that the Moon is 43 per cent oxygen, 20 per cent silicon, 19 per cent magnesium, 10 per cent iron, 3 per cent calcium, 3 per cent aluminium, 0.42 per cent chromium, 0.18 per cent titanium and 0.12 per cent manganese.

100 MORE DWARF PLANETS...

AAS In 2005, data collected in 2003 revealed the existence of Eris – a dwarf planet even smaller than Pluto out beyond the orbit of Neptune.

99 STARS HAVE LIMITS

NASA In the 1920s, solar physicists established the Eddington limit, a cap on how bright a star can get while the outward force balancing the inward push of gravity is stable.

98 THE SOLAR SYSTEM'S COOL SHELL

AAS The first of three Kuiper Belt objects was discovered by Dave Jewitt and Jane Luu in 1992, leading to the realisation there's an icy band of comets at the edge of the Solar System.

97 THE SUN'S STRANGE OUTER ATMOSPHERE

NASA The outermost part of the Sun's atmosphere is not usually visible due to it being washed out. Ultraviolet emissions from the corona were first detected on 10 October 1946.

96 IMPOSSIBLE RING

AAS In 2023, icy dwarf planet Quaoar, half the size of Pluto, was found to have a strange ring system further from its parent body than any seen in the Solar System before, challenging ring-formation theories.

95 GALACTIC CANNIBALISM

NASA Scientists find that galaxies grow by smashing together and merging, finding evidence such as stretched-out 'tidal tails' of stars and gas around other galaxies.

© Getty

94
EARTH IS NOT ALONE
The Greeks discovered the five planets visible to the naked eye over Earth: Mercury, Venus, Mars, Jupiter and Saturn. They called them 'planets', which means 'wanderers' in Greek.

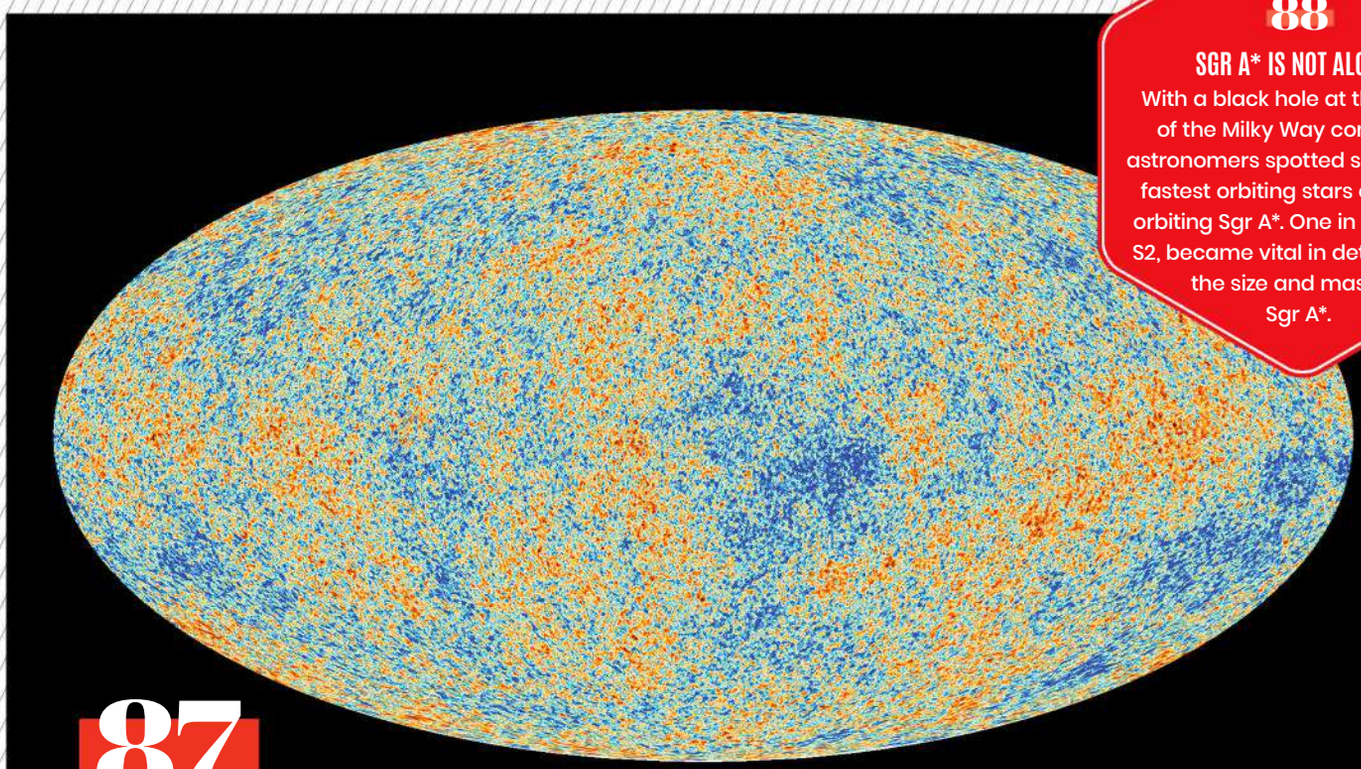
93
URANUS IS REVEALED
In 1781, William Herschel discovered Uranus, an ice giant and the seventh planet from the Sun. It was the first object to be classified as a planet with a telescope.

92
ANOTHER ICE GIANT
The eighth planet from the Sun, Neptune, was found by astronomers on 23 September 1846. The discovery was made by mathematically considering perturbations in the orbit of Uranus.

91
PLUTO: ONCE THE NINTH PLANET
In February 1930, Pluto was discovered at the edge of the Solar System by Clyde Tombaugh and was classified as the Solar System's ninth planet.

90
THE MAIN ASTEROID BELT MANIFESTS
18th-century German astronomer Johann Titius predicted the existence of a band of small bodies between Mars and Jupiter prior to his death in 1796.

89
THE FIRST ASTEROID
Giuseppe Piazzi discovered the first asteroid, Ceres, on 1 January 1801. Ceres is the largest body in the main asteroid belt and is now considered a dwarf planet – the only one in the inner Solar System.



88
SGR A* IS NOT ALONE
With a black hole at the centre of the Milky Way confirmed, astronomers spotted some of the fastest orbiting stars ever seen orbiting Sgr A*. One in particular, S2, became vital in determining the size and mass of Sgr A*.

87
PIGEON POO OR COSMIC FOSSIL?

The cosmic microwave background (CMB) was discovered accidentally in 1965 by Arno Penzias and Robert Wilson using a large radio antenna in New Jersey. They initially chalked the microwave background hum filling the universe to pigeon poop on their equipment, but after clearing pigeons from the Holmdel Horn Antenna, this was eliminated. CMB radiation is a fossil left over from just after the Big Bang. The discovery won Penzias and Wilson the Nobel Prize in Physics in 1978. The CMB dates back to an event in the early universe called the last scattering. Prior to this event, the cosmos was opaque to light, with photons endlessly scattered by a soup of free electrons and thus prevented from travelling. After around 370,000 years, the universe had expanded and cooled enough to allow electrons and protons to unite and create the first atoms of hydrogen – a period called the 'Epoch of Reionisation'. As a result, photons could suddenly travel, and the universe instantaneously became transparent to light. This first light – the first free photons – is seen today as the CMB, surrounding the universe almost completely evenly.

86

HOW MARS BECAME THE RED PLANET

AAS Since its discovery, the blood-red hue of Mars has been its defining characteristic, with it getting its name from iron being exposed to oxygen on the Martian surface.

85

SUNSPOTS BECAME CLEAR

NASA In 1908, George Ellery Hale found that dark patches on the Sun's surface, sunspots, are connected to the twisting of the Sun's intense magnetic fields.

84

THE PEAK OF MARS EXPLORATION

AAS In 1971, Mariner 9 discovered Olympus Mons, a mountain on Mars two-and-a-half times as large as Mount Everest – Earth's highest peak.

83

FURTHER AND FASTER THAN EVER

NASA The Parker Solar Probe became the fastest object ever created by humanity as it raced past the Sun at 635,266 kilometres (394,736 miles) per hour on 27 September 2023.

82

SHAKING THINGS UP ON MARS

AAS In 2019, the InSight lander detected seismic waves rippling through Mars, confirming the existence of a geological phenomenon termed 'marsquakes', which were first detected – but not confirmed – by the Viking spacecraft.

81

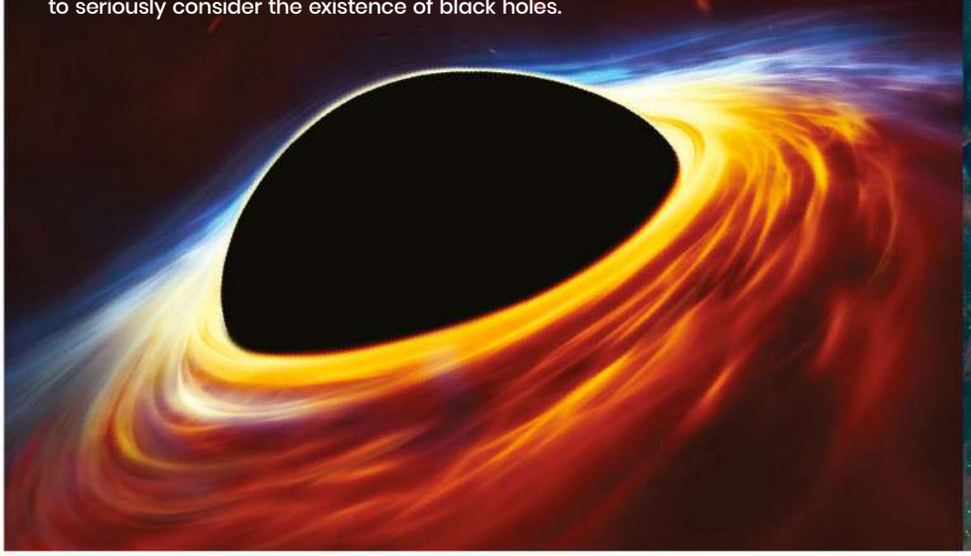
COLLISION COURSE

ESA In 2012, using the Hubble Space Telescope, astronomers discovered that the Milky Way and Andromeda are heading towards each other and are set to collide and merge. Andromeda is currently 2.5 million light years away, and the two galaxies are predicted to meet in around 4 billion years.

80

BLACK HOLE BIRTH PROCESSES DISCOVERED

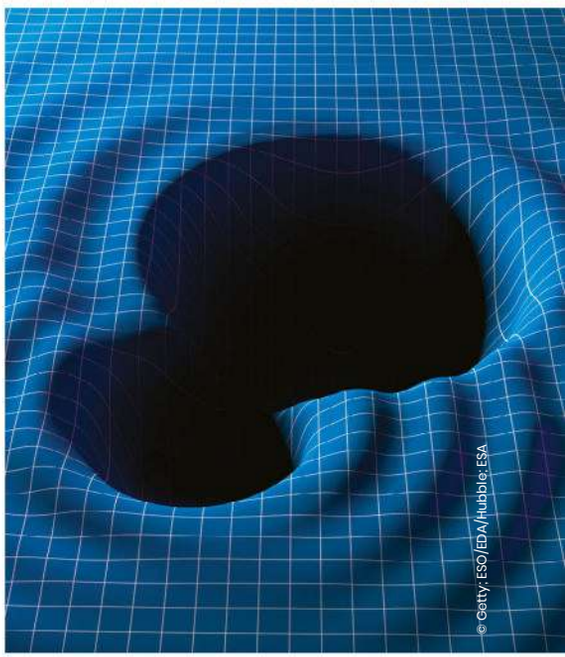
UoS The existence of black holes had been revealed by solutions to the equations at the heart of Einstein's general relativity, but even the great physicist wasn't entirely sure that black holes actually existed. It was in 1939 when the 'father of the atom bomb' Robert Oppenheimer and colleagues calculated that these regions of space-time so dense and compact that they have an escape velocity greater than light itself could be birthed by the collapse of the most massive stars. They developed a model of black hole birth that sees stars at the end of their fuel for nuclear fusion collapse, triggering a massive supernova explosion. As the outer layers are blown away in this blast, the collapsing core becomes a black hole. This model is still used today and was key to scientists really starting to seriously consider the existence of black holes.

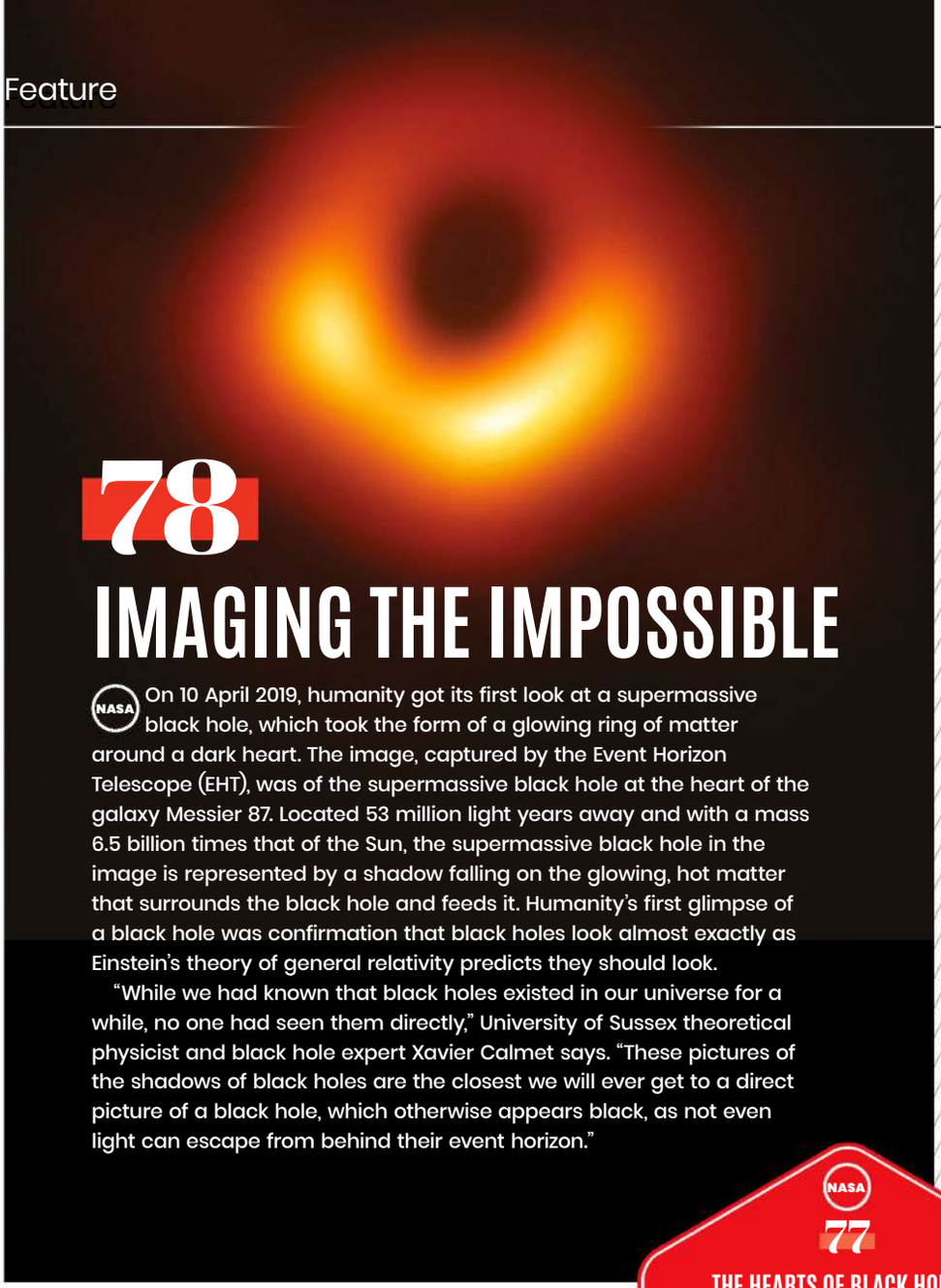


79

GRAVITATIONAL WAVES MEASURED FOR THE FIRST TIME

LIGO Gravitational waves are tiny ripples in the fabric of space-time that Einstein predicted would arise when any body with mass accelerated. On 14 September 2015, the Laser Interferometer Gravitational-Wave Observatory (LIGO) and Virgo gravitational wave detectors picked up the faint signal of gravitational waves from a merger between a 36-solar-mass and 29-solar-mass black hole around 1.3 billion light years away. The signal was designated GW150914 – GW for 'gravitational wave' and the numbers representing the date of observation.





78
IMAGING THE IMPOSSIBLE

NASA On 10 April 2019, humanity got its first look at a supermassive black hole, which took the form of a glowing ring of matter around a dark heart. The image, captured by the Event Horizon Telescope (EHT), was of the supermassive black hole at the heart of the galaxy Messier 87. Located 53 million light years away and with a mass 6.5 billion times that of the Sun, the supermassive black hole in the image is represented by a shadow falling on the glowing, hot matter that surrounds the black hole and feeds it. Humanity's first glimpse of a black hole was confirmation that black holes look almost exactly as Einstein's theory of general relativity predicts they should look.

"While we had known that black holes existed in our universe for a while, no one had seen them directly," University of Sussex theoretical physicist and black hole expert Xavier Calmet says. "These pictures of the shadows of black holes are the closest we will ever get to a direct picture of a black hole, which otherwise appears black, as not even light can escape from behind their event horizon."

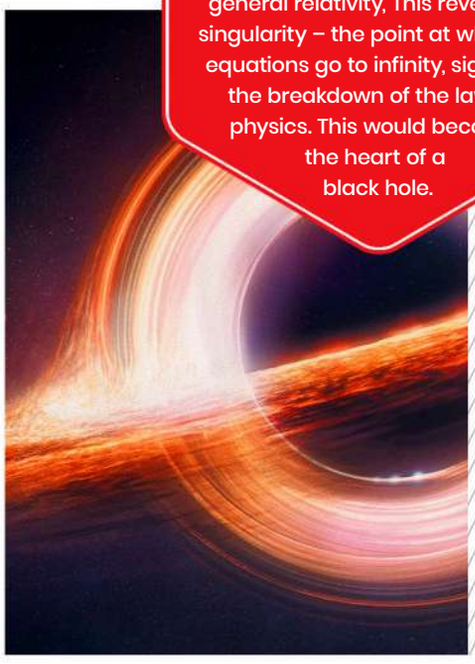
NASA

77
THE HEARTS OF BLACK HOLES

Karl Schwarzschild developed the first solution to the equations of general relativity, This revealed a singularity – the point at which the equations go to infinity, signalling the breakdown of the laws of physics. This would become the heart of a black hole.

76
THE EVENT HORIZON IS BORN

ESA While working with his solution to Einstein's theory of general relativity, German astronomer Karl Schwarzschild calculated that all astronomical bodies would have an escape velocity, known as the Schwarzschild radius. For most bodies, this radius would be deep within them, but for highly compressed massive objects like black holes, the Schwarzschild radius is outside their limits. For black holes, this is their outer boundary – the light-trapping surface known as an event horizon, before which no information can escape a black hole, which protects the mystery of the central singularity.



75
THE RIGHT STUFF

AAS Scientists confirm that Mars once had the right chemistry to support life as NASA's Curiosity rover discovers sulphur, nitrogen, oxygen, phosphorus and carbon on Mars – all key ingredients necessary for life.

74
THE SOLAR WIND IS FOUND

NASA Physicist Eugene Parker theorised in the 1950s that the Sun is surrounded by solar wind that would be visible in the solar halo during an eclipse and when its particles strike the Earth's atmosphere, creating the northern lights.

73
DIAMONDS ARE FOREVER

AAS Uranus and Neptune may look like inert, blue snowballs from a distance, but the discovery that diamonds may rain through the atmospheres of the ice giants in 2017 showed they might be the most 'alien' worlds in the Solar System.

72
EXOMOONS

ESA In January 2022, astronomers found what seems to be a moon orbiting a planet outside the Solar System. The first potential exomoon orbits a Jupiter-sized planet called Kepler-1708 b and appears to be 2.6 times as large as Earth – larger than any moon in the Solar System.

71
A VERY VOLCANIC MOON

AAS Jupiter's rocky moon Io was discovered to be the most volcanic body in the Solar System, the result of tidal forces caused by the gravity of Jupiter and the other Galilean moons squashing and squeezing it.

70

A STAR OLDER THAN THE UNIVERSE?

AAS After observing HD 140283, a star located 190 light years from Earth, astronomers estimated it to be 16 billion years old – older than the universe.

69

ANCIENT ECLIPSES

NASA Accounts of solar eclipses date back as far as 3340 BCE. Pre-Socratic Greek philosopher Anaxagoras is credited with offering the first scientific explanation.

68

TWO'S COMPANY

AAS John Michell discovered in 1767 that some stars are actually binary stars – two stars that are gravitationally bound together and orbit around each other.

67

THE MOON IS SHAKING

NASA Instruments placed across the lunar surface by the Apollo missions collected seismic data between 1969 and 1977, showing 'moonquakes' rock the Moon.

66

NOT ALL STARS ARE LIKE THE SUN

AAS By the early 20th century, astronomers realised stars come in different sizes, temperatures, masses and colours, with blue hotter than red and yellow.

65

THE COSMIC WEB

ESA Dark matter binds galaxies on large scales. In 1996, Richard Bond coined the phrase 'cosmic web' to describe this twisted structure of filaments and clumps formed by dark matter.

64 MARS HAS A WATERY PAST

C Modern-day Mars is the template of a dry, barren and lifeless planet, defined by its dust and rock-strewn surface. But it wasn't always this way. Though it's now arid, scientists have long suspected that Mars flowed with water in its past. Confirming this, the NASA Mars rovers Curiosity and Perseverance both explore what experts believe were once overflowing bodies of water. Curiosity has been exploring the 155-kilometre (96-mile) wide dry lakebed of Gale crater, estimated to be about 3.5 to 3.8 billion years old, since August 2012. Meanwhile, Perseverance has been trundling through the 45-kilometre (28-mile) wide Jezero crater since February 2021, drilling free rock samples from an area believed to have been the junction of river channels almost 4 billion years ago. The clearest evidence of water on Mars yet was delivered by the Curiosity rover in 2023 as it explored an ancient lakebed, finding ancient water ripples that stirred up sediments that left textures in rocks billions of years ago.

ESA

63

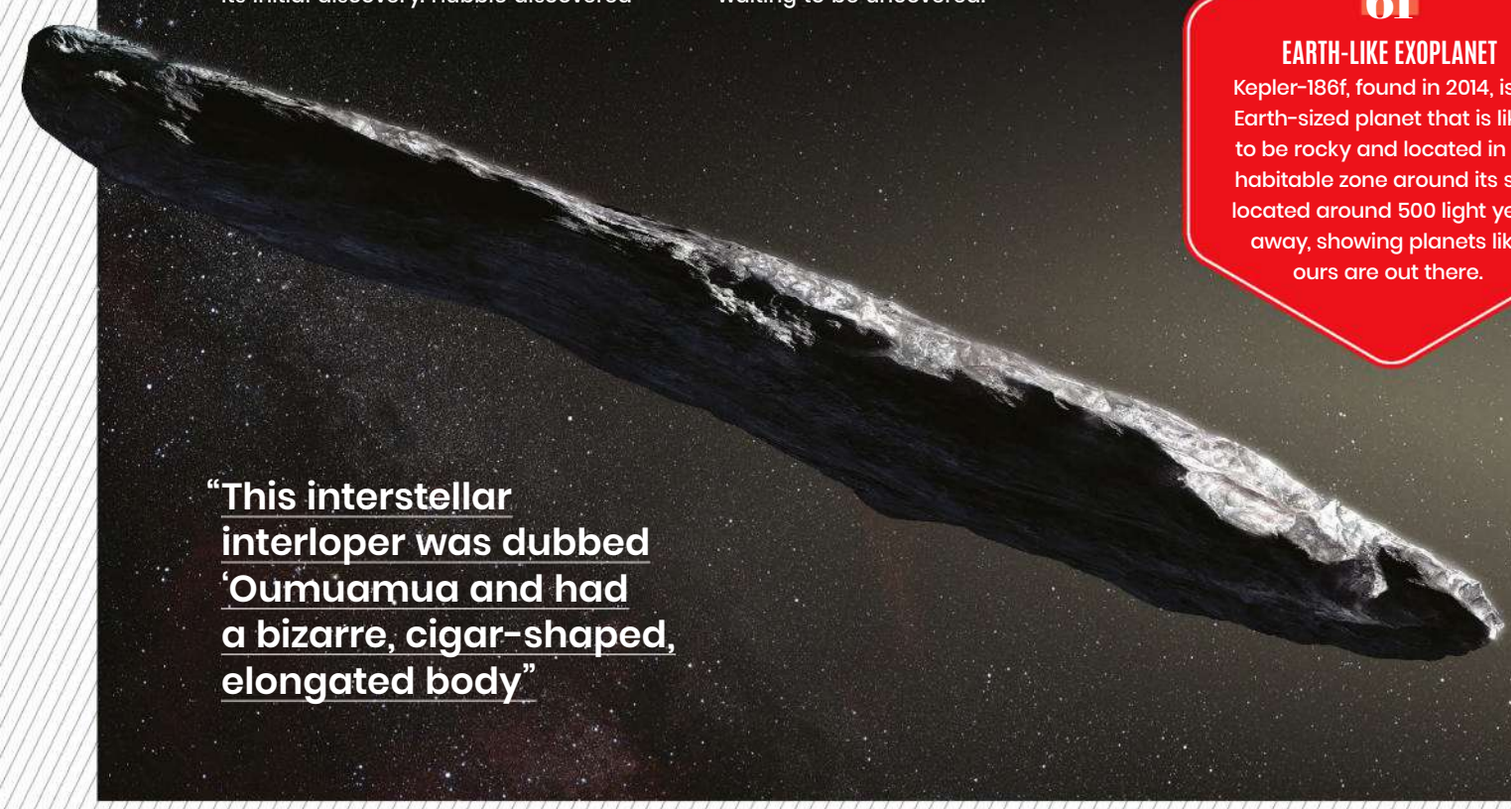
AN ODD-SHAPED PLANET

WASP-103 b, Spotted in 2022 by the CHaracterising ExOPlanets Satellite (CHEOPS), is a planet squashed into a rugby-ball-like shape by the tidal forces generated by its star.

© Getty, EHT Collaboration; NASA/JPL-Caltech

62
SOLAR SYSTEM INVADERS

ESO On 19 October 2017, astronomers discovered the first known interstellar object visiting our Solar System from beyond its outer reaches. This interstellar interloper was dubbed 1I/2017 U1 'Oumuamua and had a bizarre, cigar-shaped, elongated body that still perplexes scientists six years after its initial discovery. Hubble discovered a second interstellar object in 2019, this time a comet with a more traditional shape, named Comet 2I/Borisov. 'Oumuamua and 2I/Borisov are reminders of a much wider cosmos outside the Solar System and suggest that the Solar System might contain many more extrasolar interlopers just waiting to be uncovered.



"This interstellar interloper was dubbed 'Oumuamua and had a bizarre, cigar-shaped, elongated body"

ESA

61
EARTH-LIKE EXOPLANET

Kepler-186f, found in 2014, is an Earth-sized planet that is likely to be rocky and located in the habitable zone around its star, located around 500 light years away, showing planets like ours are out there.

60
STELLAR NURSERIES ARE BORN

AAS In 1610, Nicolas-Claude Fabri de Peiresc discovered the Orion Nebula – a glowing cloud of gas and dust. This is a region of active star formation and is the closest such region to Earth.

59
THE SUN HAS DEPTH

NASA The Sun isn't just an amorphous blob of super-hot gas, consisting of six main layers: the core, radiative zone, convective zone, photosphere, chromosphere and corona.

58
THE FIRST NEUTRON STAR

AAS In 1967, the first neutron star was detected in the form of a repeating radio signal using a large radio telescope at the Mullard Radio Astronomy Observatory by Jocelyn Bell Burnell.

57
THE MOON WAS VOLCANICALLY ACTIVE

NASA After landing on the Moon in 1969, the Apollo 11 mission revealed that the Moon was hot when it formed and that it was magnetically active for at least 800 million years.

56
PULSATING FIND

ESA Scientists discover that 'pulsing stars' that periodically brighten are spinning neutron stars that sweep radiation over Earth with every pulse.

55
THE UNIVERSE IS FLAT

ESA Earth might not be flat, but in 2003 physicist David Spergel measured tiny variations in the CMB, finding the amounts of positive and negative energy suggest the universe is flat.

54
SUNSPOTS

NASA Sunspots became a gauge of the Sun's activity. In 1613, changes in the position of sunspots confirmed that the Sun rotates monthly.

53
PLANETARY MOTION

ESA From 1609 to 1619, Johannes Kepler developed his laws of planetary motion, describing the orbits of the planets as ellipses, the area these orbits cover and the link between orbital size and orbital period.

52
THE FIRST NEAR-EARTH ASTEROID

NASA The first near-Earth asteroid, 433 Eros, was discovered in 1898 by Carl Gustav Witt and Felix Linke at Urania Observatory in Berlin and Auguste Charlois at Nice Observatory.

51
THE BIGGER THEY ARE, THE FASTER THEY FALL.

NASA More massive blue stars are hotter, and thus burn their hydrogen fuel faster and 'die' faster – or, more accurately, move off the main sequence of the Hertzsprung-Russell diagram more quickly.

50
SOME ASTEROIDS FOLLOW THE LEADER

NASA In 1906, astronomer Max Wolf of Heidelberg-Königstuhl State Observatory discovered the Trojan asteroids, space rocks trapped in the orbit of Jupiter stuck following the gas giant around the Sun.

49
EARTH'S MAGNETIC BUBBLE

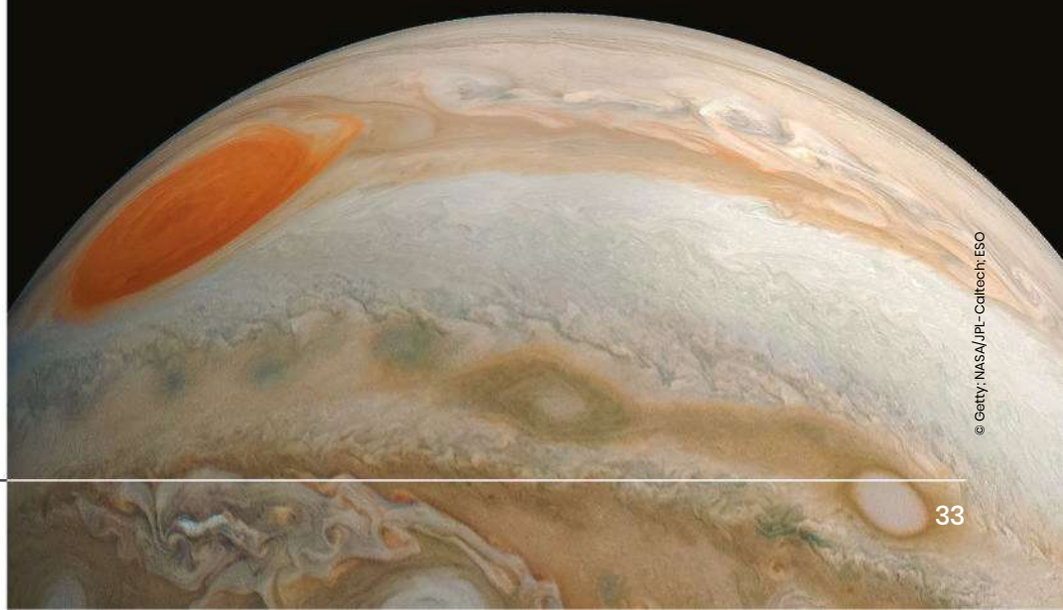
AAS Explorer 1 discovered that Earth is surrounded by a magnetic bubble called the magnetosphere in 1958. This protects the planet's surface from bombardment by energetic particles.

48
TWO EXOPLANETS AT ONCE

NASA For as long as we've known that distant stars are bodies like the Sun, we've theorised about the planets that may orbit them. As shocking as it may sound, until the mid-1990s, we weren't completely sure that other stars hosted planets. That changed with the first detection of a duo of planets outside the Solar System, called extrasolar planets or 'exoplanets'. These two new worlds, called Phobetor and Poltergeist, were discovered in 1992 by Aleksander Wolszczan and Dale Frail. Both rocky planets are orbiting a rapidly spinning neutron star blasting out jets of radiation – the pulsar PSR B1257+12 is located around 1,170 light years from Earth.

47
THE BIGGEST STORM IN THE SOLAR SYSTEM

ESA The Solar System's largest storm, the Great Red Spot, was discovered raging across the atmosphere of Jupiter by either English scientist Robert Hooke in 1664 or by Italian astronomer Giovanni Cassini a year later. This persistent, high-pressure region of the atmosphere of Jupiter is an anticyclonic storm given its name due to its reddy-orange hue, the cause of which is still uncertain. We now know this storm is currently 16,350 kilometres (10,159 miles) wide – 1.3 times the width of Earth. In 2021, Juno discovered the depth of this red storm, finding that it sinks at least 483 kilometres (300 miles) into the atmosphere of Jupiter.



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46

SOLAR WIND MEASURED

NASA In 1959, the Soviet Luna 1 became the first spacecraft to directly observe the solar wind – streams of charged particles emitted by the Sun – and measure its strength.

45

FIRST COMET FOUND WITH A TELESCOPE

NASA Observations of comets date back to 289 BCE, but significant development in this practice occurred in November 1680, when Gottfried Kirch discovered the first comet with a telescope.

44

GALAXIES HAVE INVISIBLE HALOS

ESA Building on the work of Vera C. Rubin, scientists discovered that dark matter seems to envelope most – if not all – galaxies in halos extending well beyond their stars and gas.

43

THE SUN BLOWS ITS TOP

NASA The first observation of a massive outflow of stellar material from the Sun, called a coronal mass ejection (CME), was observed by Orbiting Solar Observatory 7 (OSO-7) on 14 December 1971.

42

LAGRANGIAN POINTS

ESA These are gravitationally stable points between two large masses, such as the Sun and Earth. Scientists now use these to 'park' satellites like the James Webb Space Telescopes around our planet.

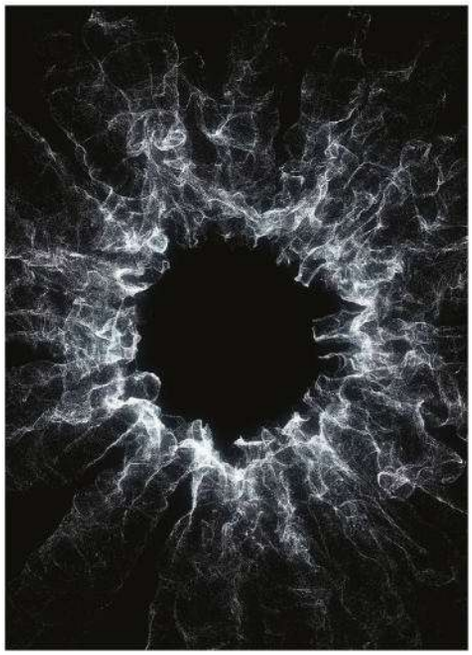
41

TOUCHING THE SUN

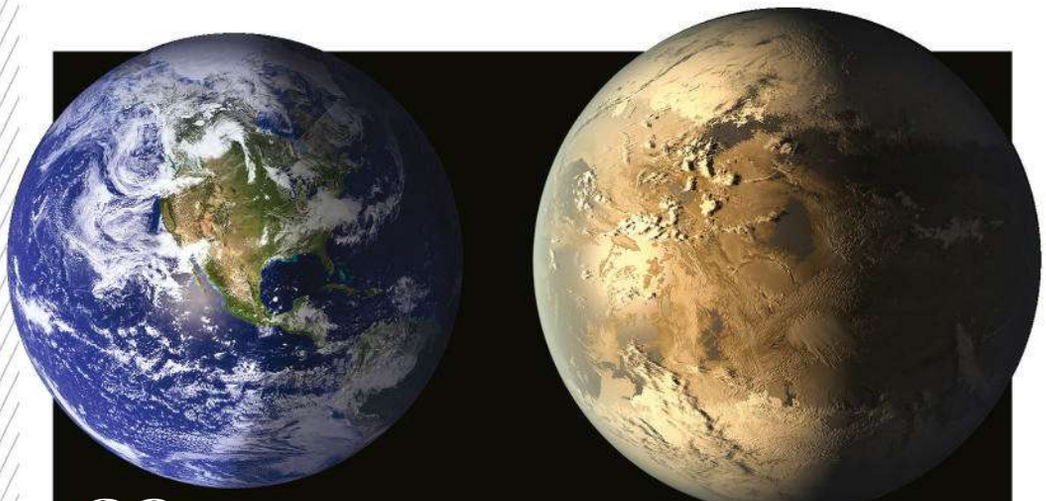
NASA The Parker Solar Probe came within 10.4 million kilometres (6.5 million miles) of the Sun's surface and became the first spacecraft to 'touch the Sun' when it flew through the solar corona in April 2021.

40

FASTER AND FASTER



NASA By observing the redshift of distant supernovae in the late 1990s, two teams of astronomers discovered that not only is the universe expanding, it's doing so at an accelerating rate. "This wasn't expected because if all types of matter and energy in the universe were attractive, it would stop its expansion, recollapse at some point and end up in a 'Big Crunch' – a stage opposed to the initial Big Bang," Garcia adds. "The accelerated expansion of our universe means there must be a missing ingredient in the total budget that overcomes gravity's attractive force due to 'negative' pressure." Dark energy was introduced at this time as a placeholder for whatever is expanding the fabric of space-time.



39

THERE IS NO EARTH 2.0

NASA Humanity is constantly discovering worlds that resemble ours outside the Solar System, many of which dwell in the habitable zone of their stars. Yet as our planet becomes more inhospitable and more turbulent due to the effects of climate change, it would be wrong to look at these worlds as alternatives for humanity to settle in the near future. That's because of the sheer magnitude of the distance between our planet and these worlds, which makes exoplanet colonies pure science fiction at the moment. As an example, consider the closest star system to the Solar System, Proxima Centauri, four light years away, and imagine there's an Earth-analogue planet around that star. The fastest human-carrying spacecraft is the Orion module, which races through space at a top speed of 38,624 kilometres (24,000 miles) per hour – around 16 times as fast as the top speed of a F-16 jet fighter. Even travelling constantly at this top speed and assuming no diversions, it would take Orion over 119,000 years to reach the Proxima Centauri planetary system. Until the invention of near-light-speed travel or suspended animation, Earth is the only planet we've got... we must protect it.

"WASP-76 b is an extraordinary discovery because of the sheer violence of this exoplanet"

38

THE BOILING EXOPLANET WHERE IT RAINS IRON: WASP-76 B

IGO Discovered in 2013 as it crossed the face of its parent star, WASP-76 b wasn't the first exoplanet found, nor was it the first hot Jupiter, so what makes it a discovery fit for this list? WASP-76 b is an extraordinary discovery because of the sheer violence of this exoplanet, which makes our gas giants look a bit tame. Orbiting its star at a distance of just 0.033 times the distance between Earth and the Sun, WASP-76 b completes an orbit in just 1.8 Earth days. The planet, which is 1.83 times the width of Jupiter and 0.92 times the mass of the Solar System's gas giant, is tidally locked. This means that one side of the planet permanently faces its parent star, while one side perpetually faces space. This sends the temperature of the 'dayside' facing the star soaring to 2,400 degrees Celsius (4,350 degrees Fahrenheit), while the nightside, facing space, is relatively cooler at 1,500 degrees Celsius (2,730 degrees Fahrenheit). Temperatures at the dayside are so hot that iron is vaporised; it's then blown across to the nightside by powerful winds, where it cools and falls as iron rain.

ESA

37

OUR PLACE IN SPACE

Where in our vast galaxy is our home around the Sun located? In 1785, William Herschel performed counts of stars in the Milky Way and determined where Earth and the Solar System are located in our galaxy. But Herschel incorrectly placed the Solar System close to the heart of the Milky Way. As observations of the stars have proven him wrong, astronomers have shifted our position to 26,000 light years from the galactic centre to sitting perched at the inner edge of the Orion arm.

36

MISSING TYPE OF EXOPLANET

ESA As they discover more exoplanets, astronomers discover a curious absence of Neptune-sized worlds close to their stars, terming this the 'hot Neptunian desert'.

35

DARK STARS

ESA In 1783, John Michell suggested the existence of stars so dense that not even light could escape them. In 1796, Pierre-Simon Laplace suggested a similar idea, terming them 'dark stars'.

34

DIFFERENT TYPES OF SUPERNOVAE

ESA The light spectrum coming from different supernovae shows these events have different origins, including Type Ia coming from the explosion of feeding white dwarfs.

33

HOW TO MAKE A TELESCOPE

ESA In 1608, spectacle makers in The Netherlands Hans Lippershey and Zacharias Janssen and Dutch instrument-maker Jacob Metius created the first telescopes.

32

RED AND BLUESHIFT

ESA The discovery that Doppler shift applied to the wavelength and frequency of light was crucial for the discovery that the universe is expanding and for modelling the motion of stars.

31

THE FINITE SPEED OF LIGHT

ESA Astronomer Ole Rømer proposed in 1676 that light has a finite speed in a vacuum, eventually determined to be 1,080 million kilometres (671 million miles) per hour.

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30

THE UNIVERSE ISN'T STATIC

ESA Realising that the universe isn't static thanks to Edwin Hubble, Einstein removes the cosmological constant from his equations.

29

AN EXPANDING UNIVERSE

ESA Cosmologists reintroduced the cosmological constant to account for the accelerating expansion of the universe and to describe the energy density of empty space.

28

COSMIC RAYS

ESA During a series of balloon flights from 1911 to 1912, Austrian physicist Victor Hess detected charged particles entering Earth's atmosphere from space, eventually ruling out the Sun as a source.

27

GAMMA-RAY BURSTS

ESA On 2 July 1967, Vela 4A made the first measurement of a gamma-ray burst – powerful blasts of high-energy radiation that come from the birth of black holes and violent cosmic events.

26

THE SPEED LIMIT OF THE UNIVERSE

ESA In 1905, Einstein developed special relativity, setting the speed of light in a vacuum, or 'c', as a cosmic speed limit that no object with mass can exceed.

25

RETHINKING SPACE AND TIME

ESA In 1908, Hermann Minkowski suggested the three dimensions of space are united with the fourth dimension of time, forming a four-dimensional entity called space-time.

ISRO

24

WATER ON THE MOON

In 2008, a study of lunar rock revealed water molecules trapped in volcanic glass beads. Also in 2008, India's Chandrayaan-1 found water molecules trapped in ice in craters at the lunar poles. The discovery of water across the Moon becomes even more significant as humanity prepares to return to the lunar surface.

23

SEVEN EARTH-LIKE WORLDS

NASA The TRAPPIST-1 system is a planetary collection of seven planets orbiting a cool red dwarf star, located around 40 light years from Earth. Its discovery earns its place on this list because all of these exoplanets seem to have rocky compositions and are around the same size as Earth. Even more excitingly, three of these worlds orbit their star in the so-called habitable zone – the region around a star neither too hot nor too cold for a planet to host liquid water. The first two planets of the TRAPPIST-1 system were discovered in 2016, with the remaining five following soon after.

The conditions these worlds exist in make them golden targets for searching for the conditions needed to support life, and even for biosignatures – chemical fingerprints in an exoplanet's atmosphere that may have been produced by the processes of life. The James Webb Space Telescope made a beeline for the planets of the TRAPPIST-1 system in its first year of operations, making observations of TRAPPIST-1 b, a super-Earth with 1.4 times the mass and 1.1 times the width of our planet. Webb has measured the temperature of this planet using its thermal emissions, which is the first time any light emitted by an exoplanet has been measured.

22

PRECIOUS METALS

ESA Neutron star collisions are determined as violent and turbulent sites in which gold, platinum and other elements heavier than lead are forged, with the detection of tellurium at such a site in 2023.

21

LUNAR CRATERS OBSERVED AND UNDERSTOOD

CU The origins of the around 30,000 craters on the Moon would begin to become clearer in the 20th century, with meteorite bombardment confirmed as the cause.

20

A STAR OR A PLANET?

IAC In 1995, Rafael Rebolo López, María Rosa Zapatero-Osorio and Eduardo Marín Guerrero de Escalante confirmed the existence of the first brown dwarf, Teide 1, in the Pleiades, 400 light years from Earth.

19

THE OLDEST GALAXIES

NASA In its first release of data, Webb spotted galaxies which date back as far as 13.3 billion years, which means we are seeing them as they were when the universe was just 500 million years old.

18

THE COSMIC DISTANCE LADDER

NASA Astronomers can measure cosmic distances thanks to the development of a series of scaling methods in a system called the cosmic distance ladder. Each 'rung' is calibrated using the prior rung.

17

ELECTROMAGNETIC SPECTRUM

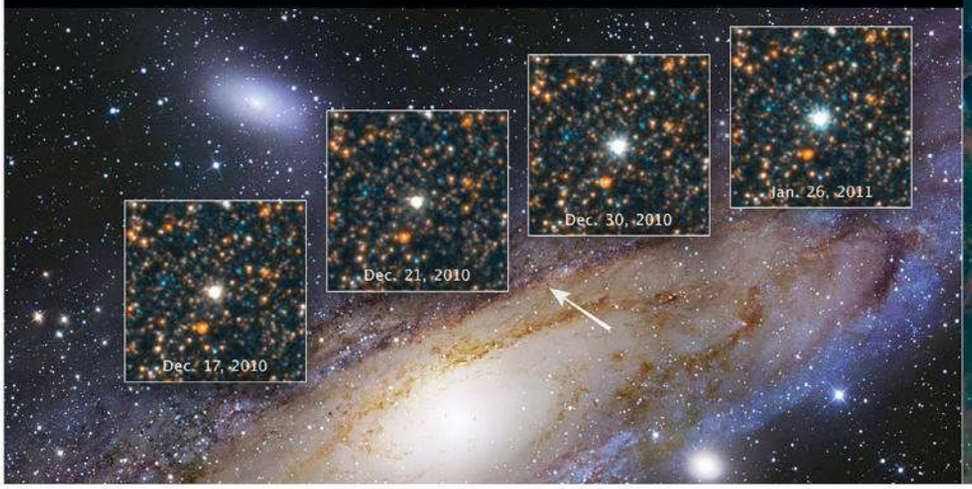
NASA It was the combined effort of scientists including Johann Wilhelm Ritter, Heinrich Hertz and William Herschel in piecing together the spectrum, including radio, X-ray, infrared, visible, gamma and microwave.

16

THE MILKY WAY IS NOT THE ONLY GALAXY

ESA In 1923, Edwin Hubble discovered conclusively that there are galaxies outside of the Milky Way. As strange as it sounds, the question of whether other galaxies exist had been hotly debated prior to this. Hubble focused on Andromeda, a fuzzy spiral in the sky that many astronomers believed was located within the Milky Way itself and was a nebula of gas and dust – a stellar nursery where stars are born. Hubble disputed this, with he and other scientists perplexed by some odd features of Andromeda, such as the large number of supernovae within it and the relative faintness of these cosmic explosions.

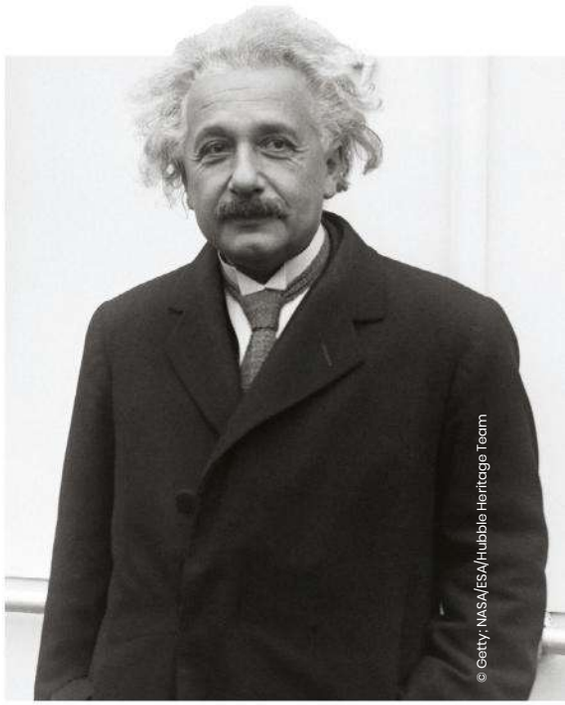
Along with Heber Curtis of Lick Observatory, Hubble proposed that Andromeda was an 'island universe', a system of stars all of its own. Hubble confirmed this by measuring the distance to V1 – a variable star labelled the most important star in the history of cosmology – showing that Andromeda was definitely a galaxy and proving the existence of galaxies outside the Milky Way.



15

GENERAL RELATIVITY

NASA Black holes, gravitational waves, gravitational lensing and neutron stars all owe their origins to general relativity. What this revolutionary idea suggested was that rather than being a force, gravity arises from a curvature of the very fabric of space and time caused by the presence of mass. The analogy for this is a stretched rubber sheet with balls of increasing mass placed on it. The greater the mass, the more extreme the dent. Stars create more curvature than planets, and black holes create more curvature than stars. The more extreme the curvature, the stronger the gravity in this region of space, informing matter how it should move around it. This explained the orbit of the planets and more.

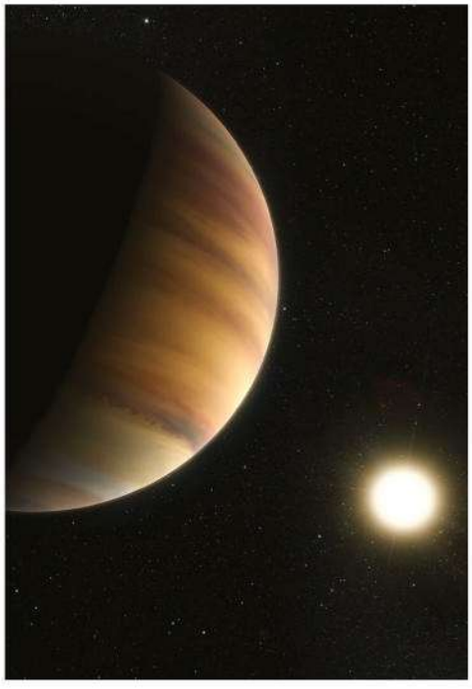

© Getty: NASA/ESA/Hubble Heritage Team

14
SEEING THE COSMIC GIANT AT THE HEART OF THE MILKY WAY

EHT The second supermassive black hole that was imaged by humanity was the supermassive black hole at the centre of our home galaxy. In May 2022, the EHT Collaboration revealed to the world an image of Sagittarius A* (Sgr A*), the supermassive black hole that lurks at the heart of the Milky Way, around 26,000 light years from Earth. Despite the fact that Sgr A* is so much closer to our planet, the reason it wasn't the first black hole imaged is the massive size disparity between it and the black hole at the heart of Messier 87. Sgr A* is relatively small at 4.5 million times the mass of our star. Sgr A* is also far less wide than this more distant black hole, but the material around it still whips around it at near-light speeds. As a result, gas around Sgr A* completes an orbit over a period that is much quicker than the observing time of the EHT, making it more difficult to resolve and produce an image.

13
EXOPLANET AROUND A SUN-LIKE STAR

NASA In 1995, 51 Pegasi b was discovered orbiting a Sun-like star by astronomers Michel Mayor and Didier Queloz. 51 Pegasi b is a hot Jupiter, a categorisation given to planets with sizes and masses comparable to that of Jupiter that orbit their parent star at incredibly close proximities, resulting in blisteringly hot surface temperatures and planets unlike anything found in the Solar System. At a distance equivalent to around 0.0527 times the distance between Earth and the Sun, 51 Pegasi b completes an orbit of its parent star in just 4.2 Earth days. The exoplanet has a mass 0.46 times that of Jupiter but is 1.27 times the width of the Solar System's gas giant.



12
A PLANET NO MORE

IAU Pluto's demotion was because it met all but one criteria for a planet. It orbits the Sun and has the mass needed to assume a near-round shape, but it hasn't cleared out other bodies from its region of space.

11
GALILEAN MOONS

NOIR In January 1610, Galileo discovered the large moons of Jupiter, now known as Galilean moons: Io, Europa, Ganymede and Callisto. Galileo determined these were bodies orbiting Jupiter and not distant stars.

10
BIG STARS STICK TOGETHER

NASA The more massive a star is, the more likely it is to be found with one or two companions in a multi-star system. Currently, 75 per cent of massive stars in the Milky Way are believed to have a binary companion.

9
THE MID-LIFE CRISIS OF THE SUN

ESA During the 20th century, our star was aged at 4.6 billion years. It's halfway through the hydrogen fuel at its heart, which via nuclear fusion transforms into helium. Our star will begin to die in around 5 billion years.

8
THE ORCHESTRA OF THE COSMOS

NANO The North American Nanohertz Observatory for Gravitational Waves detected complexity in the universe's symphony, detecting low-frequency gravitational waves for the first time.

7
THE UNIVERSE DOESN'T REVOLVE AROUND YOU

NASA In 1543, Nicolaus Copernicus put forward the then-radical theory that Earth revolved around the Sun, and not vice versa. It would take over 100 years for this to be accepted.

6

ENERGY AND MASS

ESA Special relativity includes the most famous equation in history – the relationship between energy and mass, $E=mc^2$, which tells us that the energy (E) released when mass (m) is converted to energy is equivalent to that mass times the speed of light squared (c^2). The energy-matter equivalence also showed how stars create energy, vital for living things.

5

LIGHT TAKES A TURN

SU Due to the curvature of space-time, when light passes an object of huge mass, its path is curved. In an effect called gravitational lensing, this curving can amplify background light or make a single object appear at several places in the same image. This is used today by astronomers in observing early galaxies, ordinarily too distant and too faint to see.

4

INTERMEDIATE-MASS BLACK HOLES

CU In November 2004, astronomers discovered GCIRS 13E, a cluster of stars near the heart of the Milky Way that's believed to harbour an intermediate-mass black hole. In 2020, Australian astronomers witnessed what they believed was the birth of one of these middle-mass black holes, with a mass around 150 times that of the Sun.

3

A JUMBO DISCOVERY

NASA In October 2023, scientists revealed a curious discovery in the Orion Nebula: around 400 free-floating bodies. With planetary masses, the objects are theorised to have formed like stars, not like planets. The astronomers who discovered these objects using the James Webb Space Telescope have named them Jupiter-Mass Binary Objects, or JuMBOs.

NASA

2

HITTING OUT AT ASTEROIDS

In September 2022, NASA discovered what happens when you smack an asteroid really hard. The Double Asteroid Redirection Test (DART) launched on 24 November 2021 and reached its target binary asteroid system, Didymos, the following September. When it arrived, the kinetic impactor slammed into the smaller of these two asteroids, Dimorphos, changing its orbital period.

1

BIRTH OF THE BIG BANG

UNC In 1931, Georges Lemaître, a Belgian cosmologist and priest, introduced the first formulation of the Big Bang theory – the concept that the universe began as an infinitesimally small point of dense energy that rapidly expanded. It was a radical departure from the 'steady state' theories of the universe that were commonly accepted in the 1930s. This discovery also meant that the universe wasn't eternal; time had a beginning, with a cosmic clock that started at that initial moment of rapid expansion around 13.6 billion years ago.

"We know the universe is expanding, and there are a plethora of different observations that validate this idea. If we look back to the past and reverse the equations that define the evolution of the space-time continuum, we are led to discover that the universe was smaller and denser in its early stages," says Garcia. "Therefore, there would have been a point in time when the universe was incredibly small – a singularity where our laws of physics stopped applying. This event, called the Hot Big Bang, defines the beginning of time in our universe." Our models of the universe and its evolution stretch back to this initial moment, showing that everything we see today came from the most infinitesimal of beginnings.

© Getty EHT Collaboration

CREWED MISSION TO AN ASTEROID

Sending crewed expeditions to near-Earth asteroids will help us discover more about their formation and structure

Asteroids can tell us a great deal about the formation of our Solar System and could be the stepping stones to the long-term colonisation of the Moon and interplanetary trips to Mars and beyond. They might well contain water and air that could be used to support deep-space crewed missions, and there's the possibility of mining them for their precious metals. They certainly have the potential to enhance human existence, yet there are at least 1,000 dangerous asteroids that pose a risk to Earth.

Back in April 2010, then-President Barack Obama announced that NASA should send a crewed mission to an asteroid. The plan was to use a combination of the Orion spacecraft and a Deep Space Habitat (DSH) to go beyond Earth orbit. The habitat would consist of a four-person habitation module and would be suitable for 60-day missions. With an additional Multi-Purpose Logistics Module linked via a utility tunnel and docking module to the habitation module, it could operate for 500 days. These modules would be based on existing, already-proven International Space Station designs and technology. Either option would be propelled by a cryogenic propulsion stage using liquid hydrogen or liquid oxygen engines, and in future by more advanced ion engines.

The DSH would also carry a small two-person Multi-Mission Space Exploration Vehicle (MMSEV). This would take the astronauts from the DSH to a nearby asteroid, where they could obtain geological samples and carry out science experiments. Testing of a prototype Generation 2A MMSEV has already been conducted at Johnson Space Center, which involved two astronauts spending three days and two nights living inside it. Using virtual-reality headsets and a rig to suspend the astronauts to reproduce weightlessness, they evaluated simulated extravehicular activities (EVAs) on the surface of an asteroid. Other training projects are dealing with living in deep space for long periods of time. These plans all depend on funding, but in the long-term, visiting, exploring and mining asteroids could give a tremendous boost to new industries and further the exploration of our Solar System.

1 Grappling arm
This would enable the crew to explore the surface and obtain rock samples.

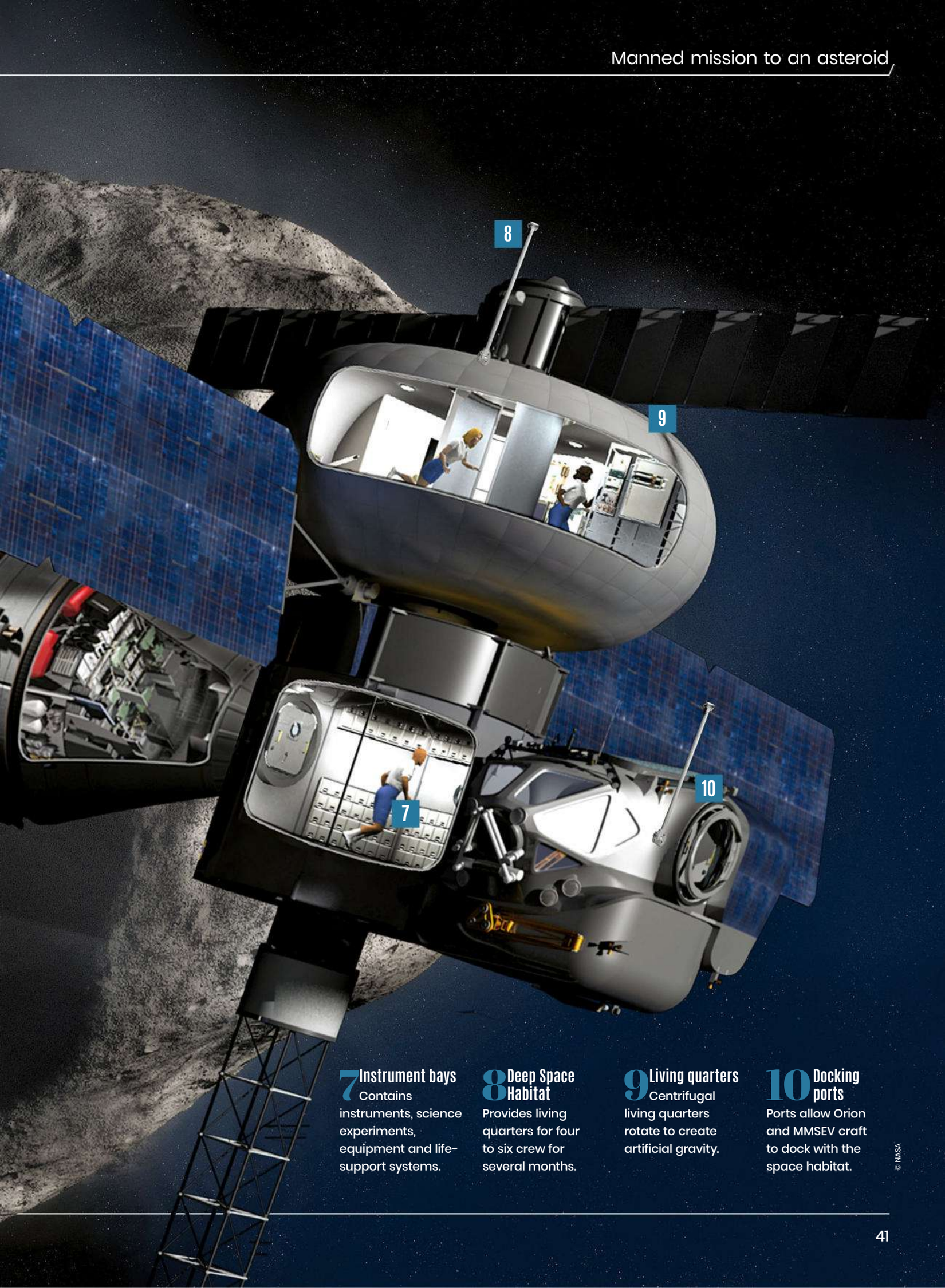
2 MMSEV
The MMSEV would transport a two-person crew to and from the space habitat.

3 EVAs
Using an airlock, one crew member can go outside to conduct EVAs on the surface.

4 Solar panels
The large solar arrays convert sunlight to electrical power. This powers all systems.

5 Orion spacecraft
Orion can carry four or more astronauts beyond low-Earth orbit.

6 Asteroids
NASA has identified 40 that could be accessed by crewed craft in a year-long mission.



7 Instrument bays
Contains instruments, science experiments, equipment and life-support systems.

8 Deep Space Habitat
Provides living quarters for four to six crew for several months.

9 Living quarters
Centrifugal living quarters rotate to create artificial gravity.

10 Docking ports
Ports allow Orion and MMSEV craft to dock with the space habitat.

© NASA

BIO+

Geoff Notkin

Notkin wears many hats; the former punk rock musician is a science writer, photographer, traveller and businessman. But most of all, he is a meteorite specialist who has appeared in programmes for some of the world's top broadcasters, such as the BBC, National Geographic and PBS. He is best known for co-hosting the hugely popular Science Channel programme *Meteorite Men* with Steve Arnold.

Geoff Notkin: Meteorite Man

"It took me years to find my second!"

The world expert on meteorites and presenter of award-winning adventure TV series *Meteorite Men* talks of his ongoing search for space rocks

Interviewed by David Crookes

When did you first develop a passion for space and meteorites?
I was mad about science from a very early age. My dad was a keen amateur astronomer who was always setting up his telescope, often fruitlessly, in Surrey, and one of my earliest memories is of my dad waking me up in the middle of the night, wrapping me in a blanket and carrying me out to the lawn to look at the Moon and Jupiter through the telescope. I had a cosmic aspect instilled into my childhood almost from the beginning, and my unconventional parents supported my growing passion.

Did you often go hunting for meteorites?
I saw meteorites for the first time at the Geological Museum in London, which is now part of the Natural History Museum, and I would love to blame it for my very unusual life. I would implore my mother to let me skip school and go there, which we did frequently, and I remember on my second visit entering a small, dark, moody area that was almost foreboding. There were these giant meteorites, and I remember thinking they had to be models because they were so big. I couldn't believe they had real meteorites from space just sitting there on a display column. But they were all real, and that sparked a lifetime of fascination. I was always rockhounding out in the Surrey chalk quarries and going down to Dorset to look for fossils.

How did you go from that to hunting for meteorites as a way of life?
That's where it gets complicated. Meteorites fascinated me throughout my childhood and through my teens and 20s. But I'm a musician as well. I became very involved with the punk rock scene in London in the 1970s, and then I moved to the US and played professionally for many years, so I was somewhat distracted by rock and roll. But I still always had a fascination for meteorites and astronomy, and whenever I was travelling and touring I always wanted to go to a planetarium or museum. In my early 30s, I said enough is enough: I must have a meteorite. I went, as a complete novice, out into the desert, and I was lucky enough to find one on my first adventure. I thought, "That was easy! I'm always told how rare they are and how difficult they are to find." It took me two years to find my second, which brought me back down to Earth.

When did you meet Steve Arnold, your co-host on *Meteorite Men*?
It was in 1996. He sent me an email after doing a global online search to see who had mentioned meteorites in their profile. He said he found seven people in the world, and had spammed all of them, but I was the only one who had replied. He was doing meteorites full time, recovering them as a career, and he was the only person I knew other than me who was interested in them. He was already quite an experienced meteorite hunter; he'd travel around to farms in the Midwest,

© Aerolite Meteorites Inc

The Science Channel show *Meteorite Men*, hosted by Notkin and Steve Arnold, has proven to be incredibly popular

Some meteors create huge impact craters when they smash into Earth

The CR2 carbonaceous chondrite known as NWA 10256 has proven to be scientifically important

The Atacama Desert is one of the most dangerous terrains on Earth, but it's home to many fallen meteorites

contact farmers, locate meteorites and trade them with museums and collectors on behalf of the finders.

Did you instantly click with each other?

The first time we met was when Steve told me he was going to the Atacama Desert in Chile on this big meteorite-hunting expedition and asked if I wanted to go. I went with a complete stranger to one of the most dangerous deserts on Earth, and my friends said that I was completely insane – what if he was a serial killer? I love classic movies, and I'm a big fan of *The Treasure of the Sierra Madre* with Humphrey Bogart. It's a movie about gold prospectors in the West in the 1800s and how they were very successful in finding this gold but started going crazy. Will they kill each other? That's the first thing I thought of: "Oh no, what if this is a *Treasure of the Sierra Madre* situation and we find valuable meteorites and Steve hits me over the head with a shovel, buries me in the desert and I'm never seen again?" I asked him if he had seen that movie and he said, "No, I haven't... should I watch it?" And I said, "No, no, don't watch it until after we get back."

But it went well?

We had an amazing expedition: three weeks across the Atacama finding many meteorites. That was the beginning of a long friendship, and I never really came back to Earth after that. It was fascinating seeing the beautiful country of Chile and traversing the extraordinary desert where NASA sent its early Mars rover to test because it was the environment most similar to Mars on Earth. Steve and I formed a hunting partnership, and we had many adventures starting in 1997. We'd go on expeditions together and alone all over the US and Europe. I went to Siberia in search of meteorites and meteorite-related impact types.

It went from being a childhood obsession, to a mad hobby, to my entire life, and then we were contacted by a big production company in California and were asked if we would be interested in doing a show. I'd done a lot of television and been a guest on astronomy shows, and Steve and I had done three one-off shows for National Geographic, Travel Channel and Discovery, so we were very keen to do more. Our one caveat was that we wanted it to be real. We didn't want to plant meteorites or have fake drama. We wanted a real adventure show. I said I would deliver as much adventure as they could handle.

Is meteorite hunting part science, part treasure hunt for you?

I grew up on things like *Journey to the Centre of the Earth* and *King Solomon's Mines*. I loved those classic adventures and I always wanted to do that – wear the adventure hat and be out in the desert doing great deeds. When I started searching for meteorites in wild places, we had this fantastic gear and strange vehicles taking us to remote places, and we'd meet weird and fascinating people. I love to hunt and I love metal detecting, but I love the vistas too, and I'm always stopping and saying, "Look at this lizard and petrified wood." Steve is all about recovering as many meteorites as he can, and he's a good-natured guy who will roll his eyes. But I have this odd tendency to save what we call meteor-wrongs – belt buckles, plough blades, shell cases, horse shoes and so on.

So it's not just about cashing in?

Not for me. I didn't get into it because I saw it as a good way to make money. Steve did – for Steve it was always about the business, and there's nothing wrong with that.

© Aerolite Meteorites inc

He's a sharp businessman and he loves the adventure and thought it was a promising way to make a living. But I got into meteorite hunting because I wanted more meteorites for my collection, and over time I realised going around the world renting vehicles and buying high-tech equipment was expensive, so I started a company called Aerolite Meteorites Inc. I felt that meteorites are everywhere, and they represent travel through the Solar System and space, so we should be accessible worldwide.

Are any meteorites expensive? You mentioned the Tucson Ring Meteorite on one of your shows...
You can find a meteorite of almost any value, so they start from a few pennies, but there's almost no limit to how high the value can go. There are some meteorites in museum collections and on display in the spot where they fell, and you couldn't even calculate the value – I don't think the Smithsonian would sell the Tucson Ring for £1 billion [$1.22 billion]. It's one of the most iconic and beautiful examples of an extraterrestrial visitor and one of the cornerstones of its collections; it's one of the greatest pieces in the world. But it's important to note that their value is not just monetary. My initial drive and fascination with this field was the wonder of meteorites, and that has never changed. I founded the company and became a commercial vendor so that I could find more specimens and make them more available to collectors and universities and educate the public. That's a huge part of our work.

Did *Meteorite Men* help you in your work?
Meteorite Men has been seen by tens of millions of people all over the world. It aired on Discovery networks and other stations for years worldwide and I cannot even estimate how many new meteorites have come to light because of it: I can think of at least ten off-hand that we acquired because people called and said, "Hey, we saw your show and my dad found a meteorite in the 1950s and we still have it." And some of these meteorites were completely new to science. It was important to educate and delight people. The show helped make meteorite collecting an international phenomenon.

What scientific value do meteorites have?
We acquired a meteorite called Northwest Africa (NWA) 10256. If you're not aware of the naming conventions, most meteorites are named after the nearest town to where they were found. If they are found in Antarctica or the deserts of Northwest Africa and there are no towns or features nearby, they are given a number. This means it was the 10,256th meteorite found in the Northwest African deserts since people began to discover them there in the 1990s. One may be a little scrap or 100 kilograms – there are that many different finds. I met with a gentleman who showed me five little pebble-like rocks, each about the size of an egg, which he had acquired in Morocco. They're definitely meteorites. I thought there was something unusual about them, so I sent them to a highly respected institution here in the US where they removed a slice and examined it under a microscope. It was determined to be an extremely rare type that we've never had on sale in our career.

What makes it so rare?
It's largely made up of carbonaceous chondrite material of type CR2, and the reason these chondrites are so interesting to science is that they are virtually unchanged since the very beginning of the Solar System. They are made entirely of chondrules, which are believed to have formed in the solar nebula. When we find something like this and examine it, we are looking at a snapshot of an existence before time as we know it – a Solar System or universe that was just a dust cloud. These meteorites are rich in carbon, and some contain water and salt, and there's a popular theory that meteorites may have brought water and maybe the building blocks of life to Earth. I had a PhD candidate come over from the UK to look at them and take some back to Leicester for research. For me, it's about adding something meaningful to the body of knowledge about meteorites. Something we found and recognised and classified is going into the literature for all of time and is being studied by scientists now, and maybe by future generations.

Is there anywhere that you know will contain lots of meteorites, but you haven't been able to get to?
When we were producing *Meteorite Men*, Steve and I came up with a list of places that we would love to go to at the start of each season, and the production team would allow us to do five international episodes and three US to fit with the budget. There were places we wanted to go but couldn't because it was too expensive, too dangerous or there were legal restrictions. But Antarctica would be top of the list; thousands of meteorites have been found there. We also know that giant iron meteorites have been found in Cape York, Greenland, and that the Namib Desert is a fantastic site. But there are strict government regulations in West Africa about moving or removing meteorites, and as we always do everything above board, we wouldn't do what some do and smuggle them out. That means cultural property disappears and meteorites are not available to academia.

FOCUS ON

CHINA IS BUILDING THE WORLD'S LARGEST UNDERWATER TELESCOPE TO HUNT FOR 'GHOST PARTICLES'

China's forthcoming telescope will search for the origins of cosmic rays in momentary flashes of light beneath the ocean's surface

Reported by Ben Turner

Scientists in China are building the world's largest 'ghost particle' detector 3,500 metres (11,500 feet) beneath the surface of the ocean. The Tropical Deep-sea Neutrino Telescope (TRIDENT) – called Hai-Ling, or 'ocean bell' in Chinese – will be anchored to the seabed of the Western Pacific Ocean. Upon completion in 2030, it will scan for rare flashes of light made by elusive particles as they briefly become tangible in the ocean depths.

Every second, about 100 billion ghost particles, called neutrinos, pass through each square centimetre of your body. And yet, true to their spooky nickname, neutrinos' nonexistent electrical charge and almost-zero mass mean they barely interact with other types of matter. But by slowing neutrinos down, physicists can trace some of the particles' origins billions of light years away to ancient, cataclysmic stellar explosions and galactic collisions.

That's where the ocean bell comes in. "Using Earth as a shield, TRIDENT will detect neutrinos penetrating from the opposite side of the planet," Xu Donglian, the project's chief scientist, said. "As TRIDENT is near the equator, it can receive neutrinos coming from all directions with the rotation of Earth, enabling all-sky observation without any blind spots."

It's hoped that the neutrinos can be traced back to their sources

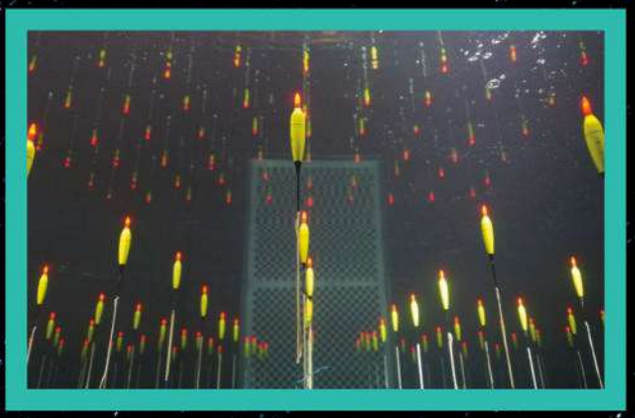
Neutrinos are everywhere – they are second only to photons as the most abundant subatomic particles in the universe and are produced in the nuclear fire of stars, in enormous supernova explosions, in cosmic rays and radioactive decay and in particle accelerators and nuclear reactors on Earth. Despite their ubiquity, their minimal interactions with other matter make neutrinos incredibly difficult to detect. They were first discovered zipping out of a nuclear reactor in 1956, and many neutrino-detection experiments have spotted the steady bombardment of the particles sent to us from the Sun. But this cascade masks rarer neutrinos produced when cosmic rays, whose sources remain mysterious, strike Earth's atmosphere.

Neutrinos pass completely unimpeded through most matter, including the entirety of our planet, but they do occasionally interact with water molecules. As neutrinos travel through water or ice, they sometimes create particle byproducts called muons that give off flashes of light. By studying the patterns these flashes make, scientists can reconstruct the energy – and sometimes the sources – of the neutrinos. But to increase the chances of ghost particle interactions, detectors have to sit under a lot of water or ice.

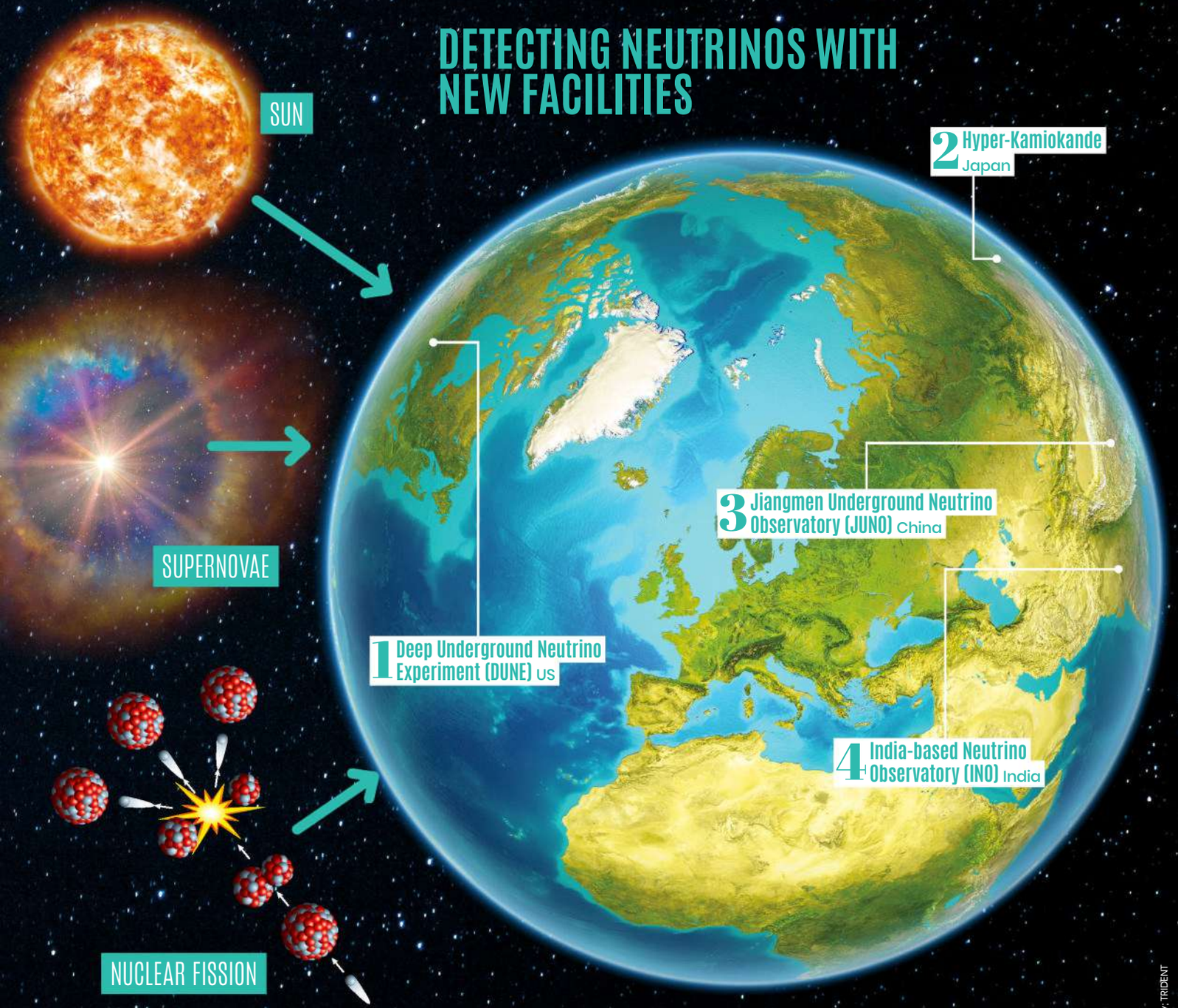
China's gigantic new detector will consist of more than 24,000 optical sensors beaded across 1,211 strings, each 700 metres (2,300 feet) long, that will bob upward from their anchoring point on the seabed. The detector will be arranged in a Penrose tiling pattern and will span a diameter of four kilometres (2.5 miles). When it's operational, it will scan for neutrinos across 7.5 cubic

kilometres (1.7 cubic miles). The world's current largest neutrino detector, IceCube, located at the Amundsen-Scott South Pole Station in Antarctica, only has a monitoring area of one cubic kilometre (0.24 cubic miles), meaning TRIDENT will be significantly more sensitive and much more likely to find neutrinos.

The scientists say that a pilot project will begin in 2026, and the full detector will come online in 2030. "TRIDENT intends to push the limits of neutrino telescope performance, reaching a new frontier of sensitivity in all-sky searches for astrophysical neutrino sources," the researchers wrote in a paper outlining the detector, published in the journal *Nature Astronomy*.



China's new neutrino detector floats in a pool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SUPERNOVAE
NUCLEAR FISSION
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FOCUS ON

THE HOME OF THE WORLD'S MOST POWERFUL TELESCOPES JOINS THE FIGHT AGAINST LIGHT POLLUTION

Chile's skies are among the darkest on our planet, attracting some of the largest observatories in the world

Reported by Keith Cooper

New standards in the fight against light pollution are helping bring darker skies to Chile, and not only will this protect our view of the stars, but also human health and biodiversity. Chile is an attractive location for astronomers because its skies are great for stargazing, particularly in the Atacama Desert, where tall peaks, a stable atmosphere and over 300 clear nights per year on average provide excellent observing conditions. As such, Chile is home to a large number of the world's most powerful optical telescopes. The European Southern Observatory is based there, with observatories at La Silla, Cerro Paranal – home to the Very Large Telescope – and Cerro Armazones, where the huge 39-metre (128-foot) Extremely Large Telescope is presently under construction. The National Science Foundation's NOIRLab also has the Gemini South Telescope, the Southern Astrophysical Research (SOAR) telescope and the Cerro Tololo Inter-American Observatory in Chile, while the 25.4-metre (83.3-foot) aperture Giant Magellan Telescope is being built at Las Campanas Observatory.

The Chilean regions of Antofagasta, Atacama and Coquimbo, which play host to these observatories, have thus had special lighting regulations for years to protect their dark-sky status for astronomers. Now, a New National Lighting Standard established by the Chilean Ministry of the Environment is being rolled out across the rest of Chile to emulate the dark-sky success of these science locations. However, the new lighting standards are not just about preserving the night sky for astronomy. Studies in many countries have shown that light pollution has a detrimental effect on both human health and wildlife. "There is increasing scientific evidence of the effects of light pollution exposure on people," Daniela González, the executive director of the non-profit Fundación Cielos de Chile, which works to protect the dark sky, said in a statement. "Numerous investigations demonstrate its incidence in pathologies such as obesity, depression, as well as breast cancer and prostate cancer."

The new standards call for the improvement of outdoor lighting, such as street lamps and floodlights, by moving away from intense blue light to softer amber hues. Illuminated advertising must also remain switched off between 00:00 and 07:00 per the ruling – imagine shutting down all advertising in New York City's Times Square or London's Piccadilly Circus for seven hours every day. "By establishing intensity, colour temperature and time limits, the New National Lighting Standard will allow a rational, efficient and sustainable use of artificial lighting, making the protection of people and the environment compatible with the good use of light," said González.

For the first time in Chile, biodiversity has also been officially recognised as under threat from light pollution, and wildlife endangered by artificial light will get extra protection. For example, insect pollinators, which play a vital role in maintaining crops, are often active at night while navigating by moonlight or bright starlight. Artificial light can confuse them, and has actually played a part in their decline.

Similarly, a seabird native to the coasts of Chile, Ecuador and Peru called the Markham's storm petrel has become endangered as a consequence of light pollution as well. The storm petrels have evolved to use the light of the Moon and stars to guide them on flights from their nests to the desert, where they breed. Urban lighting disorientates them. They often confuse it for the light of the stars and food sources, meaning many of them never even make it to the place they're headed: the Atacama Desert. "Various research evidences

that light pollution reduces biodiversity because it alters the feeding, reproduction and migration patterns of some species," said González. "This New National Lighting Standard seeks to reverse those negative impacts in those places that are strategic for conservation efforts."

And the new regulations also protect the dark-sky sanctuary that's home to the many observatories in Chile. Earlier this year, Guillermo Blanc, the president of Fundación Cielos de Chile and an associate director at Carnegie Observatories and Las Campanas, spoke of the threat to astronomy in Chile from light pollution: "The Atacama Desert has always been an extremely dark place which has unique conditions for astronomical observations, but the advance of this pollution, at the rapid and accelerated rate we are currently seeing, puts at risk the viability of the operation of astronomical observatories in the next 30 years," he said. "We risk losing the best – if not the only – place from which many observations can be made to understand and learn about the universe."

It is therefore particularly fitting that astronomy has been able to influence how people use lighting more responsibly in the rest of Chile, and that astronomy's standards for light pollution are now becoming the country's standards.

CHILE'S GIANT TELESCOPES

Extremely Large Telescope
Cerro Armazones, Chile

Gemini South
Cerro Pachon, Chile

Very Large Telescope
Cerro Paranal, Chile

Giant Magellan Telescope
Las Campanas, Chile

© Getty

WHY DOES VENUS LOOK SO YOUNG?

Unlike Earth, the second planet from the Sun only has one continuous plate. Scientists have long been trying to work out why Earth's 'evil twin' has a high level of volcanism

Reported by David Crookes

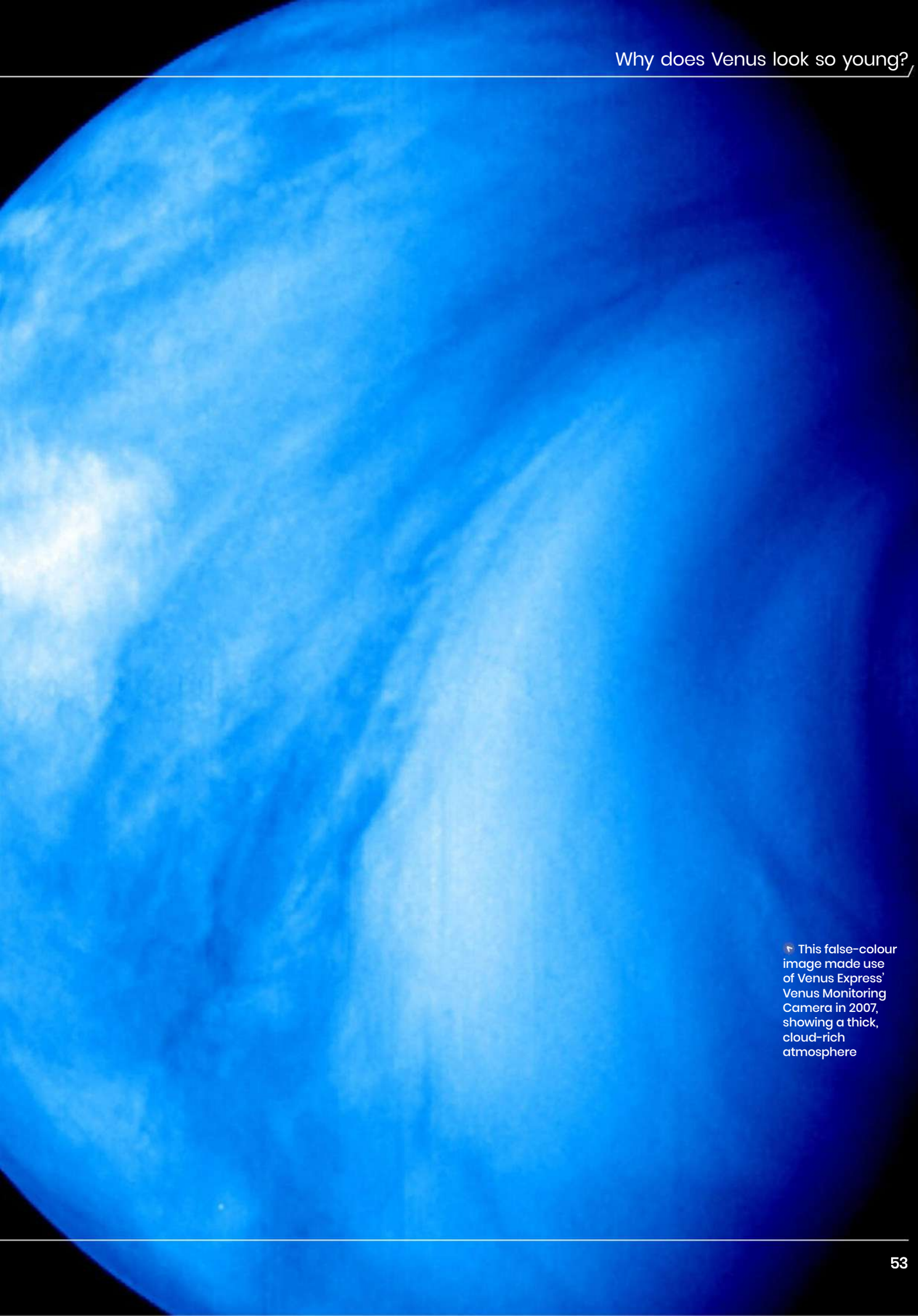
Venus has a lot of volcanoes – more than any other planet in the Solar System. What's more, the number of volcanoes counted by scientists continues to rise. In May this year, scientists revealed that the second planet from the Sun is home to more than 85,000 volcanoes, and they suspect there are even more than that, given how small so many of them are. But quite how they came to be has long been wrapped in mystery, with scientists also unsure as to how Venus has kept itself looking young.

Earth is a similar size to Venus, yet our home has just 1,500 volcanoes. Granted, most of Venus' volcanoes – some 99 per cent – are less than 3.1 miles (five kilometres) wide, but the figure of over 85,000 is nevertheless impressive given we're talking about a planet that doesn't have plate tectonics. This is a crucial difference. On Earth, volcanoes form when a tectonic plate moves under another and magma makes its way upwards, but the same simply cannot happen with Venus' single plate. It means that something else must be at play – but what that is has never been truly resolved.

"Detailed morphological studies of the surface of Venus seem to indicate that there are no obvious signs of plate margins, at least in the terrestrial sense," affirms Simone Marchi, research fellow at the Solar System Exploration Research Virtual Institute in Boulder, Colorado. Keen to get to the bottom of what may be going on, Marchi has been trying to figure out the cause of Venus' volcanism by modelling early collision histories. And it may well be that he and his team have finally cracked the case.

That the potential breakthrough comes in 2023 is no surprise. It's been an interesting year for Venus' volcanoes, with many scientists' eyes firmly locked on a planet that happens to be the second-brightest natural object in the night sky following our Moon. As well as using radar imagery collected during NASA's Magellan mission in the 1990s to count 50 times more volcanoes than past surveys, scientists have also used the same data to see direct evidence of active volcanism on Venus for the first time. Changes to a vent close to Maat Mons, one of Venus' largest volcanoes, were noted by NASA researchers in March this year, with eruptions believed to occur a few times annually. "Venus is geologically active, and this activity is peculiar when compared to Earth's," Marchi continues.

Quite aside from proving that the planet is not quite dead – and solving yet another mystery of whether Venus still had such flare-ups – volcanic activity is likely to have helped keep Venus' surface young. It's known that Venus has a young surface, dating between 200 and 700 million years old, because there are not many impact craters. "We infer a surface's age from the observed number of craters," Marchi explains. "Craters



This false-colour image made use of Venus Express' Venus Monitoring Camera in 2007, showing a thick, cloud-rich atmosphere

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VENUS BY NUMBERS

85,000
Volcanoes detected on Venus

60
times more volcanoes than there are on Earth

99%
of them are less than five kilometres in diameter

2023
Active volcanism on Venus confirmed

FOUR YEARS
The Magellan spacecraft orbited Venus between 1990 and 1994

40%
Magellan mapped more than this proportion of the planet's face

464
degrees Celsius is Venus' mean surface temperature

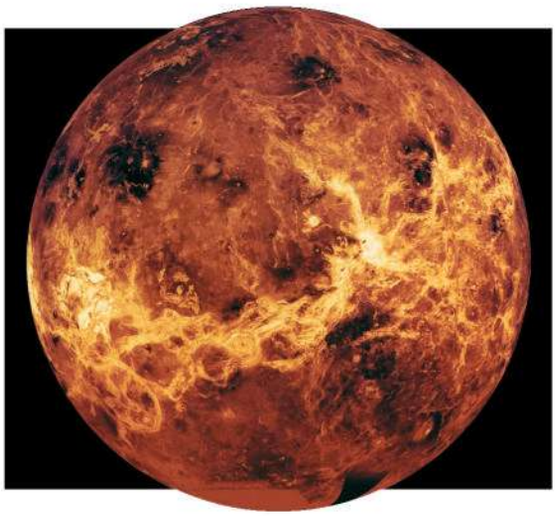
90
times the surface pressure of Earth

accumulate over time, so fewer craters indicate a younger surface. Venus has very few craters compared to, say, the Moon, Mars or Mercury, so the surface has to be young."

Since traces of the 4.5-billion-year-old planet's early surface have been vanquished, the thinking is that lava would have filled in the craters over geological timescales, giving Venus a smooth appearance. The idea was to model the early impact history of Venus to explain how this youthful surface has been maintained in the absence of plate tectonics. By drawing comparisons with Earth, the team was able to make some headway while overcoming problems with past theories and simulations that have fallen short of being able to support Venus' high level of volcanism. "Volcanoes are a way for a planet to dissipate internal heat," Marchi says. "Plate tectonics does that too, but it is lacking on Venus, and this might justify why there are more volcanoes. One issue might be how Venus' interior has been capable of sustaining intense volcanic activity for presumably billions of years. One issue with current geophysical models is [the challenge of being] able to sustain the long-lived, voluminous volcanic activity needed to explain a young surface. Some models were able to do so, but they required a combination of special circumstances, for instance the way rocks behave at high temperatures."

As such, the study team began to realise that the Solar System's early history may well have proven crucial in explaining how Venus was able to gain long-lasting heat. The team looked at the manner in which Venus and Earth were bombarded by asteroids and comets. "I realised that Venus was subjected to high impact velocities with leftover planetesimals," Marchi explains. "That led me to think what such energetic impacts might do to the long-term geophysical evolution of Venus."

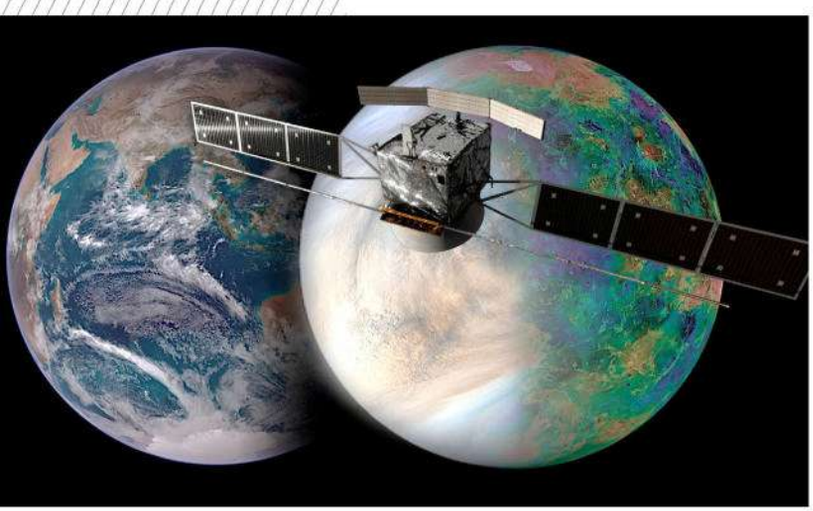
The key moment for Venus was the Late Heavy Bombardment event that, in theory, occurred between 4.1 and 3.8 billion years ago. During this period, failed planets and smaller asteroids would have slammed into the larger worlds. The study took into consideration the distances between Earth, Venus and the Sun and how that affected their impact history. The research suggests the effects of this period were felt more acutely on Venus than on Earth, and this could account for why the interior of Venus was significantly heated in comparison to our own planet. But why did the impacts of these bodies affect Venus in a different way?



Venus is closer to the Sun than Earth. It orbits our star at 126,077 kilometres (78.341 miles) per hour, and that's once every 0.615 Earth years. Since this is faster than Earth's orbit of 107,000 kilometres (67,000 miles) per hour, asteroids would have struck Venus with greater velocities. The asteroids would also have required higher orbital eccentricities to collide with Venus. In other words, small bodies smashed into Venus far more dramatically and with more power than they did on Earth.

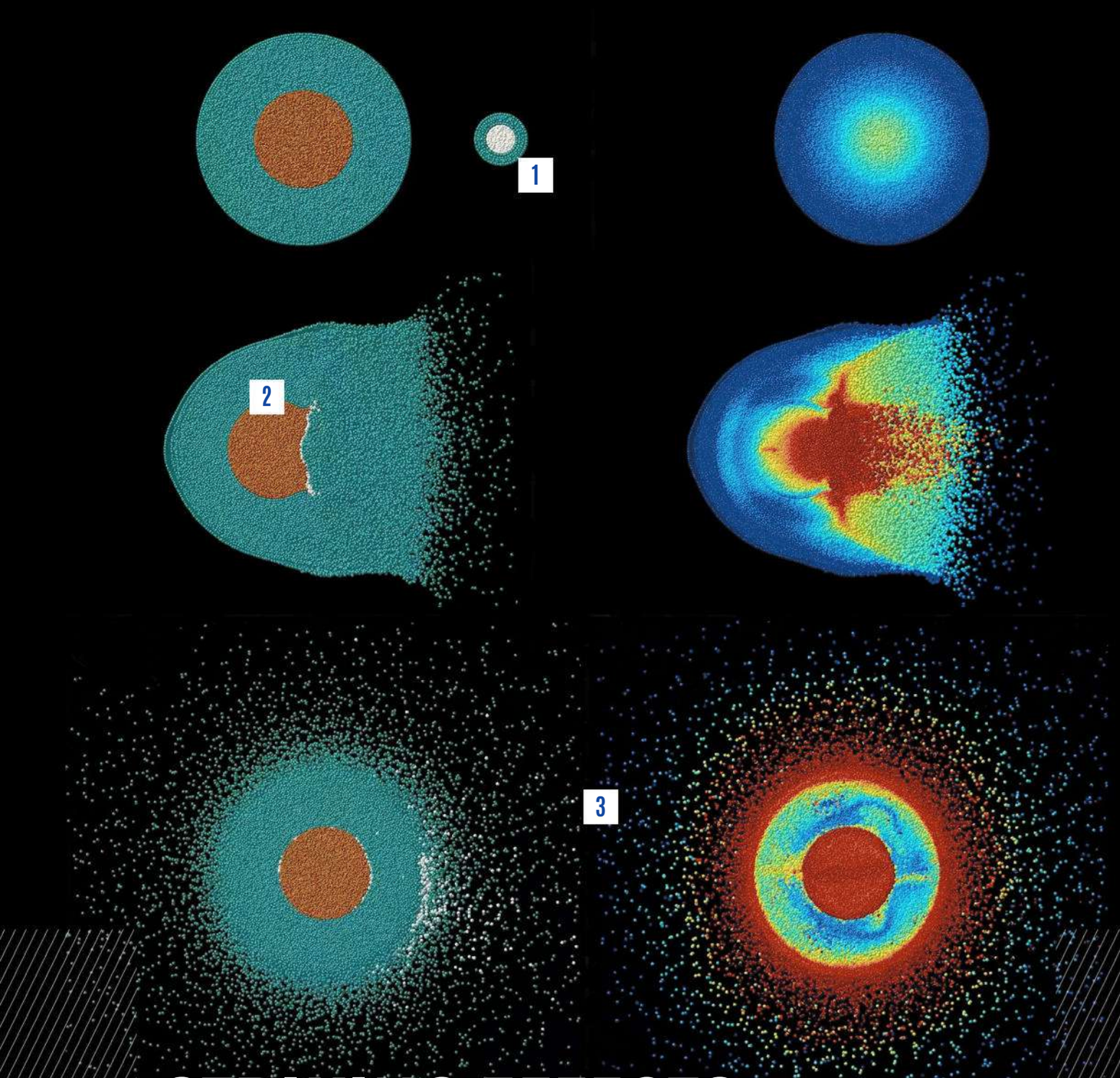
"My expertise is in impact models," says Marchi, co-author of the paper *Long-lived Volcanic Resurfacing of Venus Driven by Early Collisions*, published in the journal *Nature Astronomy*. "I started by studying high energetic collisions after realising that this was a peculiar characteristic for Venus. I did not know what to expect, except that I thought, in one way or another, this could lead to some interesting outcome. Then I presented our impact simulations and the results to an expert geophysicist, Professor Jun Korenaga, [a co-author of the study from Yale University], who was also intrigued by this new high-energy regime. He realised that the increase of core temperature would have important consequences, including long-lasting volcanism."

The simulated results, combining large-scale collision modelling and geophysical evolution, were something of a breakthrough; they found that the high-velocity impacts may have melted a high percentage of Venus' surface. "The impacts would then have affected Venus' interior,"



This global view of Venus, part-created using a global radar map, shows just how different the planet is to Earth – hotter and more hostile

The ESA's EnVision mission may be able to shed more light on why Venus has so many volcanoes



STRIKING EFFECTS

How high-energy impacts on Venus shaped Earth's twin

1 Heading for a collision

Here you can see a 3,000-kilometre (1,800-mile) diameter projectile heading towards Venus at 30 kilometres (18 miles) per second. The right side of the image shows that Venus' temperature is low.

2 The immediate effects

As the projectile collides, it hugely disturbs the silicate mantle of both objects, coloured green on the left side of the image. You can see the increased temperature changes to the right as the core and mantle heat up.

3 The aftermath

Now Venus is hotter than it was before. The silicate mantle has melted, and now there's a mixed mantle of molten materials spread across the planet, as well as a superheated core which promotes extended volcanism.

© Southwest Research Institute; NASA / JAXA

This artist's impression of an active volcano on Venus shows how life on the planet may look

© ESA

Marchi continues. "Such energetic impacts would have heated the core of Venus, and that extra heat would need to be released somehow. One way is via lots of volcanoes."

To show just how dramatic an effect this would have had, Marchi goes into detail. "The high impact speed of these early collisions on Venus had two main consequences," he tells **All About Space**. "They melted a large fraction of the planet's mantle – up to 80 per cent – and this means that any crust and solid surface that might have existed was completely wiped out. It would have been a complete reset. Some of the heat then went deep into the planet, reaching the core, again thanks to the high velocity that implies the impactor penetrated through Venus' mantle. The superheated core drove heat loss via increased volcanic activity."

All of this activity may also explain why Venus has a thick atmosphere made up of 96 per cent carbon dioxide, which is denser and hotter than Earth's. Cloud cover on the planet causes a greenhouse effect as well, which is why Venus is the hottest planet in the Solar System despite Mercury being closer to the Sun. "Our model makes predictions on the total volume of molten mantle, or lava, that would be erupted at the surface, and that matches well with the age of the surface," Marchi says. "The interesting aspect about our model is that it follows from 'first principles', meaning it's a natural outcome of planet formation. It does not require special circumstances to work."

It's a powerful and compelling theory for sure, and one that may well be proven over the next ten years thanks to two planned missions to Venus. The European Space Agency's (ESA) next Venus orbiter, EnVision, is set to launch in the early 2030s, and its aim is to work out why Venus and Earth evolved in different ways despite being roughly the same size and composition. It will do this by using a sounder to reveal underground layering and spectrometers to study both the planet's atmosphere, via the monitoring of trace gases, and its surface composition. Radar provided by NASA will image and map the surface, the ultimate overall aim being to gain a solid overview of the planet.

NASA will be aiming to make its own discoveries using the Venus Emissivity, Radio science, InSAR Topography And Spectroscopy (VERITAS) orbiter. Quite when that will be is unknown because the mission has been postponed to no earlier than 2031, but if it does get off the ground then it will map the surface of Venus to a resolution that's three times better than Magellan. Another NASA mission, Deep Atmosphere Venus Investigation of Noble gases, Chemistry and Imaging (DAVINCI), is going ahead, and this will reach Venus in the early 2030s to probe the planet's thick clouds en route to the surface.

Missions such as these could support Marchi's theory. "I hope these missions find a way to test our model – perhaps a better understanding of the internal structure, inferred from gravity measurements, may help," Marchi affirms. They could also go beyond the 40 per cent of the planet imaged by Magellan. In that sense, Marchi has his fingers well and truly crossed that this particular space mystery is well on its way to being solved. "Really, my dream would be to land on the surface and probe the composition of its rocks looking for trace elements that may reveal the past collisional history of Venus," he says. And with the Russian Federal Space Agency Roscosmos proposing to launch an orbiter and lander as part of the Venera-D mission to Venus in 2029, Marchi may well get his answers sooner rather than later.

EXPLAINING VENUS' APPARENT YOUTH

The scientific world has erupted with a number of theories over the years

There were once plate tectonics

Venus does not have tectonic plates, but some scientists have suggested that this hasn't always been the case. If so, there would need to be a reason why plate tectonics stopped about 500 million years ago. Interestingly, in 2021 it was found that the planet's outer crust was broken into small, plate-like pieces, however.

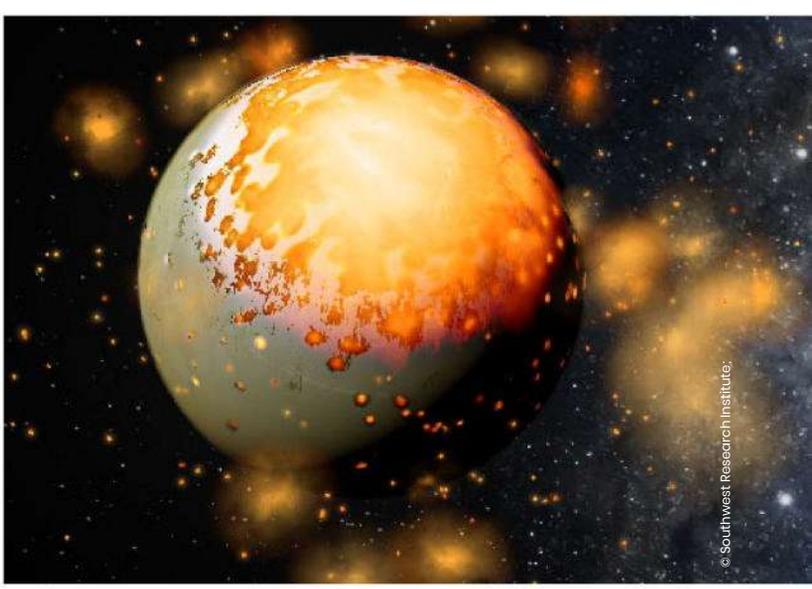
There are squishy parts of the planet

Rather than being globally stagnant and thick, there are thin regions of the planet's uppermost layer – the lithosphere – which allow heat to better escape from the planet's exterior via buoyant rising plumes of molten rock. This would point towards volcanic activity resurfacing the planet and giving it a youthful appearance.

It was given a powerful jolt

The latest theory suggests that violent impacts by fast-moving projectiles caused the planet's core to superheat to the point where it has continued to heat the mantle for billions of years. The resulting volcanic activity would cover up the majority of Venus' craters and give the appearance that the planet is younger than it is.

David Crookes
Science and technology journalist
David has been reporting on space, science and technology for many years, has contributed to many books and is a producer for BBC Radio 5 Live.



A superheated core could have created Venus' extended volcanism and a younger looking surface

FOCUS ON

‘AIR SHOWERS’ COULD HELP REVEAL COSMIC RAYS’ MYSTERIOUS SOURCES

This phenomenon could allow us to search for exotic particles such as dark matter, offering insights into the transition of the universe into a matter-dominated era

Reported by Robert Lea

Astronomers have a new way to study energetic particles that constantly bombard Earth from space, called cosmic rays. The new method proposes the detailed analysis of showers of secondary particles created when cosmic rays belt Earth’s atmosphere as a lens to better understand them. Cosmic rays are difficult to track back to a source because the charged particles that comprise them are deflected time and again by magnetic fields they encounter as they travel through space at near the speed of light. That means that their sources, which lie outside the Solar System, tend to be shrouded in mystery.

Suspects for cosmic ray sources include supernovae, but these particles seem to be too energetic to have been launched even by the explosion of massive stars. Other suspects include active galactic nuclei or quasars powered by feeding supermassive black holes, gamma-ray bursts or even exotic dark matter, but astronomers have yet to find a smoking gun that points to these sources definitively.

What is better understood is what happens when these charged cosmic particles belt Earth. When these charged particles strike particles in our planet’s atmosphere, they create a huge ‘air shower’ of secondary particles that rain down to Earth’s surface. When thousands, millions or even billions of these particles hit the ground, it’s called an extensive air shower. In a new study, scientists found a way of using precise observations of these particle showers taken with the Subaru Telescope, situated atop the Mauna Kea volcano in Hawaii, to learn more about them and the cosmic rays that trigger them. The bright tracks that extensive air showers create as they pass in front of telescopes are often a hindrance to astronomy, ruining observations of the Solar System, the Milky Way and beyond. But the research team decided to treat these streaks of light as more than pesky ‘noise’ ruining their otherwise-pristine data.

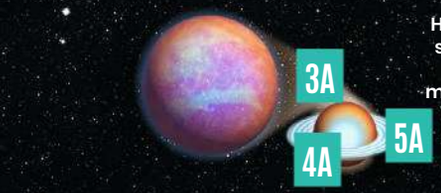
The researchers analysed around 17,000 images captured between 2014 and 2020, pinpointing 13 images that contained extensive air showers. These images showed a far greater number of particle tracks than the team had expected to see – and this could hint at a way to decode the mystery of cosmic rays. “With conventional observation methods, it’s challenging to distinguish between the types of particles that constitute extensive air showers,” team leader and Osaka Metropolitan University scientist Toshihiro Fujii said. “Our method, on the other hand, has the potential to determine the nature of individual particles.”

Scientists think cosmic rays are composed mainly of protons, around 90 per cent the atomic nuclei of hydrogen – the universe’s lightest element – nine per cent helium nuclei and one per cent other particles, including electrons and odd atomic nuclei as heavy as lead. The new study could deliver a better way to discover the particle ingredients of air showers, and in turn cosmic rays, which could then help determine their source, team members said. “By integrating our method with conventional approaches, we hope to advance our understanding of extensive air showers,” Fujii concluded. “This technique may allow us to search for dark matter or other exotic particles, offering additional insights into the transition of the universe into a matter-dominated era.”

WHEN STARS EXPLODE

TYPE IA SUPERNOVAE

1A FINDING THE RIGHT STARS
These occur when a white dwarf, like the one our Sun will leave behind after its death, is found in a binary pair with another star.



5A LIMITED GAINS
However, white dwarfs can only get so massive through accretion. The Chandrasekhar limit puts their maximum size at about 1.4 times the mass of our Sun.

6A OUTWARD PRESSURE
This time the star cannot expand to accommodate the outward pressure of its newly kindled fusion burning. Instead expansive forces build, eventually creating a violent supernova.

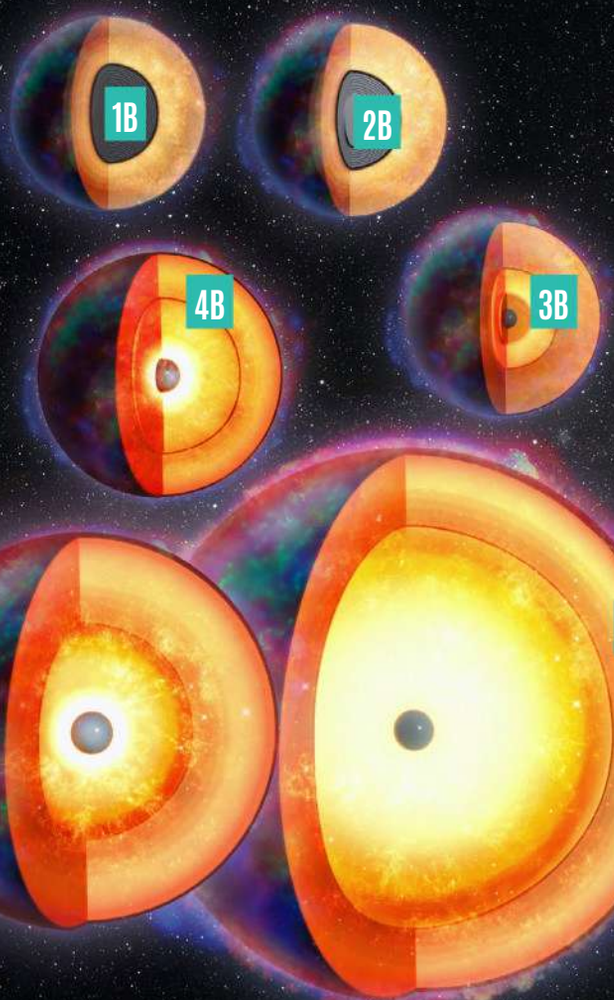
2A MATTER TRANSFER
Occasionally the two stars will orbit close enough to each other that matter will transfer from the companion onto a white dwarf in a process called accretion.

3A SQUEEZING DOWN
This accretion of matter from its companion adds extra mass. The additional gravitational forces compress the already highly pressurised core of the white dwarf.

4A A STAR REBORN
As the star approaches the Chandrasekhar limit, the dying star comes to life again and undergoes fusion in its centre.

TYPE II SUPERNOVAE

1B OUT OF GAS
Supergiants like Betelgeuse will eventually run out of hydrogen and helium fuel, the nuclear burning of which prevents them collapsing in on themselves.



4B BURNING FUELS
For stars this size, their mass and compressional forces at their cores allow them to fuse heavier elements in order to maintain the outward pressure that holds off gravity.

5B SHOCK WAVE REBOUND
This inward implosion bounces back off the core as a rebounding shock wave that blows the whole atmospheric envelope off the star, creating a spectacular supernova.

3B RESISTANCE IS FUTILE
This act of resistance holds until the star's innermost core is composed of iron, which refuses to fuse. Gravity finally wins out and the star's outer layers collapse inwards.

2B AN ELEMENTAL ONION
Gradually heavier elements build up at the star's centre, which becomes layered like an onion, with lighter elements towards the outside of the star.

COSMOLOGY

Why is space black?

The darkness of our night sky tells us more about the size, age and nature of the universe than we may expect. We are familiar with the twinkling of nearby stars in the night sky, but why does the night sky not glow with the colour and brightness of the average star? If the universe is infinite in size and age, then in every direction we look there should be a star or galaxy - well known to be powerful emitters of visible light. This puzzle is known as Olber's paradox, after 19th-century German astronomer Heinrich Olbers, and has attracted many attempts to resolve it.

The first part in resolving this paradox is that the universe must have a finite age. This means only a finite number of stars can be observed from Earth in any direction – something which is true even if the universe itself has infinite size. The second part is from the expansion of the universe, an integral part of our understanding of cosmology, known as the Big Bang model. This expansion of space, together with a finite light travel time, causes the radiation emitted in this hot, dense beginning, as well as that from distant stars and galaxies, to be shifted to longer wavelengths than are visible to the naked eye. We observe this today as the cosmic microwave background - the faint glow of emission over the entire sky, observable only with microwave detectors such as the European Space Agency's Planck mission. Ultimately, the night sky is dark to us due to the expanding, evolving and finite age of the universe.

William Alston, senior lecturer at the University of Hertfordshire

Despite being full of light sources, the sky looks dark

Mars and Venus lack a magnetic field at present

Some call brown dwarfs failed stars

SOLAR SYSTEM

Why don't all planets have magnetic fields?

The magnetic field of a planet is generated by fluid motions in an electrically conducting region of its interior. Without such motions – or if they're not vigorous enough – a planet will not have a magnetic field. For Earth, this region is the liquid outer core, which is dominantly composed of iron and nickel, and heat escaping the core powers turbulent convective flows. In a good electrical conductor, magnetic field lines tend to remain attached to material particles. These flows can twist and shear an existing magnetic field, and this is the process that can sustain it. Take away this stirring, and the field decays. For Earth this would take approximately 30,000 years. The other terrestrial planets also have metallic liquid cores, but only Mercury has a planetary magnetic field. This means that flows in the liquid cores of Mars and Venus are not vigorous enough at present, although we know that Mars had a field in the past from the magnetisation recorded in its crustal rocks. For the giant planets, the conducting region is metallic hydrogen for Jupiter and Saturn or ionised water and ammonia for Uranus and Neptune.

Mathieu Dumberry, associate professor at University of Alberta

STARS

Can a star turn into a planet?

Yes, a star can turn into a planet, but only for a particular type of star called a brown dwarf, and only if we use broad definitions of the words 'star' and 'planet'. A brown dwarf is the lightest type of star, with a mass of about 13 to 80 times the mass of Jupiter. Such a star is too low in mass to trigger the nuclear fusion of regular hydrogen like in normal stars. Instead it triggers the nuclear fusion of heavy hydrogen, which is much rarer. As a result, a brown dwarf glows like a normal star, but only dimly. Over time, a brown dwarf runs out of heavy hydrogen, cools and becomes dark. At this point it can be considered a planet. Despite the fact that it now looks and acts like a planet, a dark brown dwarf continues to sit in the middle of its solar system. Such a solar system therefore becomes a collection of smaller planets orbiting a large, dark, cold central planet. Some scientists define the words 'star' and 'planet' more narrowly, and therefore consider a brown dwarf to be neither star nor planet, in a class of its own.

Dr Christopher S. Baird, assistant professor of physics at West Texas A&M University

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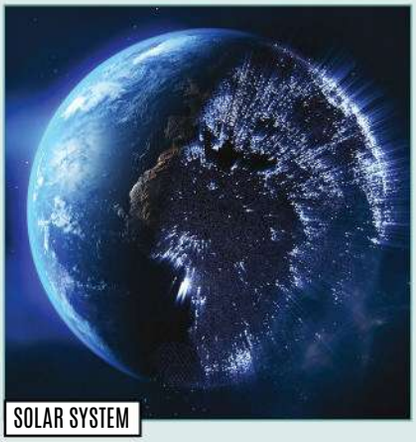


SOLAR SYSTEM

Why is Earth not a perfect sphere?

Earth isn't a perfect sphere for two main reasons. The first is that the material of Earth possesses strength unlike a simple fluid. This strength is enough to overcome the forces of gravity to some extent. If Earth was a simple fluid, it would assume the shape of minimum energy – a perfect sphere – provided Earth did not spin on its axis. However, Earth spins on its axis. The spin provides a force that acts against the force of central gravity and gives Earth a slightly flattened shape – the equatorial radius is about 30 kilometres (18.6 miles) greater than the polar radius. So even if Earth was a spinning ball of fluid with no strength, it would not be a sphere – it would have the shape of a prolate ellipsoid.

Frank J. Spera, professor emeritus at the University of California, Santa Barbara

"Even if Earth was a spinning ball of fluid with no strength, it would not be a sphere – it would have the shape of a prolate ellipsoid"

SPACE EXPLORATION

How do gravity assists help space exploration?

Gravity assists are a clever way to reach far-away planets. Imagine the Solar System as a deep 'well' of gravity with the Sun at the bottom. Earth is about halfway down. A spacecraft to any other place has to climb down or up the steep walls of the well. Both need lots of energy, so a large rocket is used. Reaching the planets Mercury, Jupiter, Saturn and beyond would be impossible – even our biggest rockets couldn't send a spacecraft there directly.

But scientists have found a solution. Every planet is a big body with a lot of gravity. A spacecraft flying close to a planet will be deflected. This can speed it up, adding energy to its trajectory. Imagine a tennis racket hitting a ball. Gravity assists work like that – without actually hitting the planet! For example, instead of flying directly to Saturn, a spacecraft might fly first to Venus, then to Earth, then to Jupiter, picking up energy each time until it has enough to reach Saturn. Gravity assists help space exploration by allowing us to send spacecraft to many places that we couldn't otherwise reach.

Michael Khan, senior mission analyst at the European Space Agency

Gravity assists allow us to explore further into space

Our planet is almost spherical, but not quite

Antarctica is the largest desert on Earth

ASTROPHYSICS

Why are conditions in Antarctica ideal for seeing the cosmic microwave background

The cosmic microwave background (CMB) is made up of photons from the primaeval oven that the universe forged the first elements within. These are the lightest elements, and when they were formed, the leftover binding energy of formation was released in the form of heat. That heat propagated throughout the universe for 13.8 billion years, until it arrived at our telescopes. If you've used a microwave oven before, you know that microwaves are efficient absorbers of water, and water is very much present in Earth's atmosphere. The atmosphere above the South Pole is very space-like – it's very desert-like. There are few water molecules in the atmosphere above the South Pole. We don't want these photons that are so precious to us, and so few, travelling across the universe, and all of a sudden they smash into a water molecule in our atmosphere. That's no good, so all of our microwave telescopes need to be built at high elevation, in very cold climates or both.

Brian Keating, professor at the University of California, San Diego, and director of the Simons Observatory

© Alamy, Getty

ASTROPHYSICS

Will Sagittarius A* eventually consume the Milky Way?

The short answer is no. First of all, the gravitational pull of Sagittarius A* is simply not enough to consume the Milky Way on its own. Perhaps most importantly, the laws of gravity are such that gravity doesn't care about the object causing the gravitational pull, just about its mass. For example, if we replaced the Sun with a black hole with the same mass and a radius of approximately three kilometres (1.8 miles), nothing would happen – besides us not getting sunlight anymore! Earth would still keep rotating around the Sun as it does, not knowing that the Sun has turned into a black hole, as its mass has remained the same. To be consumed by a black hole, you would have to plunge straight into it, which is somewhat akin to finding a needle in a haystack.

More concerning for us is the fact that in less than 5 billion years, our Milky Way will collide with our neighbour Andromeda, which at its centre hosts a supermassive black hole 100 times more massive than Sagittarius A*, and therefore 100 times as large. However, even in this case the probability of this black hole swallowing the Milky Way is still pretty low.

Dr Sunny Vagnozzi, assistant professor at the University of Trento

FOCUS ON

A MUD LAKE ON MARS MIGHT BE HIDING SIGNS OF LIFE IN CHAOTIC TERRAIN

On a drying Red Planet, water could have come bubbling up from below

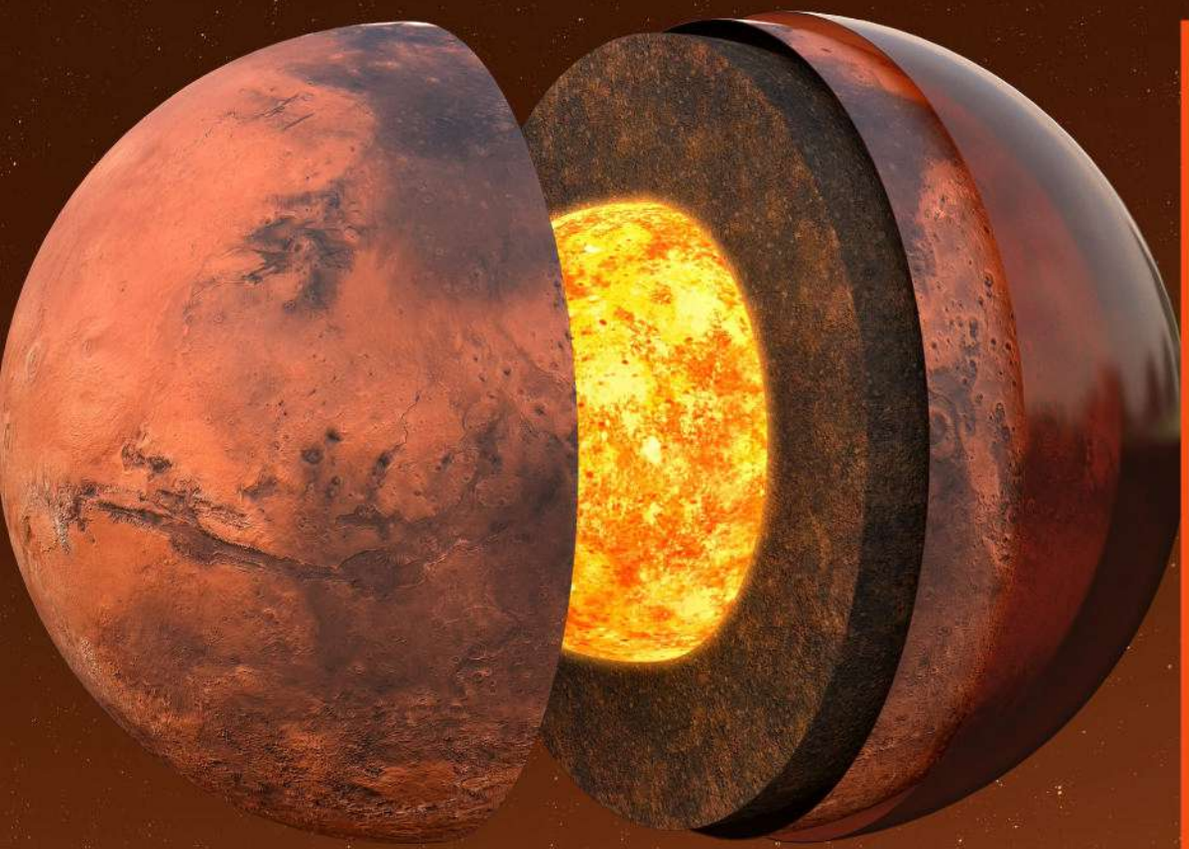
Reported by Rahul Rao

Planetary scientists want to search for biosignatures in what they believe was once a Martian mud lake. After scientists carefully studied what they think are the desiccated remnants of an equatorial mud lake on Mars, their study of Hydraotes Chaos suggested that a buried trove of water surged onto the surface. If the researchers are right, then this flat could become prime ground for future missions seeking traces of life on Mars. "While Martian lakes and mud volcanoes have been subjects of prior studies, our work represents the first comprehensive analysis specifically focused on a putative mud lake," Alexis Rodriguez, a senior scientist at the Planetary Science Institute in Arizona, said.

More generally, scientists suggest that surface water on Mars froze over about 3.7 billion years ago as the atmosphere thinned and the surface cooled. But underground, groundwater might still have remained liquid in vast chambers. Moreover, life forms might have abided in those catacombs – leaving behind traces of their existence. Only around 3.4 billion years ago did that system of aquifers break down in Hydraotes Chaos, triggering floods of epic proportions that dumped mountains' worth of sediment onto the surface, the study suggests. Future close-up missions could someday examine that sediment for biosignatures.

Hydraotes Chaos is an example of geography called chaos terrain: a jumble of jutting mountains, broken craters and jagged vales. Rodriguez and his colleagues pored over images of Hydraotes Chaos taken by NASA's Mars Reconnaissance Orbiter in search of more clues. In the midst of the chaos terrain's maelstrom lies a calm circle of relatively flat ground. This plain is pockmarked

An artist's impression of the terrain on Mars



with cones and domes, with hints of mud bubbling from below, suggesting that sediment didn't arrive via a rushing flash flood, but instead rose from underneath. Based on simulations, researchers suggest Hydraotes Chaos overlaid a reservoir of buried, biosignature-rich water, possibly in the form of thick ice sheets.

Ultimately – potentially from the Red Planet's internal heat melting the ice – that water bubbled up to the surface and created a muddy lake. As the water dissipated, it would have left behind all those tantalising biosignatures. Curiously, that water might have remained underground even after those megafloods. In fact, the results suggest that the sediment on the surface of this mud lake dates from only around 1.1 billion years ago – long after most of Mars' groundwater ought to have flooded out, and certainly long after Mars was habitable.

With that timeline in mind, the team plans to analyse what lies under the surface of the lake. That would allow scientists to establish when in Martian history the planet might have hosted life. Scientists might even be able to take future research right into the ancient mud. NASA's Ames Research Center is working on an instrument called Extractor for Chemical Analysis of Lipid Biomarkers in Regolith (ExCALiBR) that would test extraterrestrial rocks for biomarkers. A future mission might take ExCALiBR with it to the Moon or Mars. "Hydraotes Chaos is under consideration as a candidate landing site," Rodriguez said.

THE RED PLANET BY NUMBERS

15 EARTH YEARS

How long NASA's Opportunity rover lasted on Mars

95%

of Mars' atmosphere is carbon dioxide

100x thinner

The Martian atmosphere compared to Earth's atmosphere

31 kilometres

How far NASA's Curiosity rover has travelled at the time of writing

Number of successful and failed missions to Mars by NASA

SEVEN MINUTES

The time taken for a lander to get from the top of Mars' atmosphere to the surface

2.5x

more radiation is experienced at Mars than on the ISS

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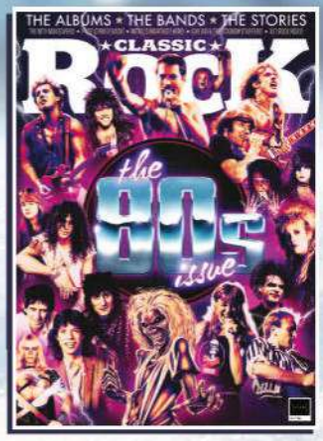

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FOCUS ON

INFRARED AURORAE ON URANUS CONFIRMED FOR THE FIRST TIME

The Keck II telescope in Hawaii is the first to see the infrared glow on Uranus, caused by hydrogen molecules in the atmosphere becoming excited

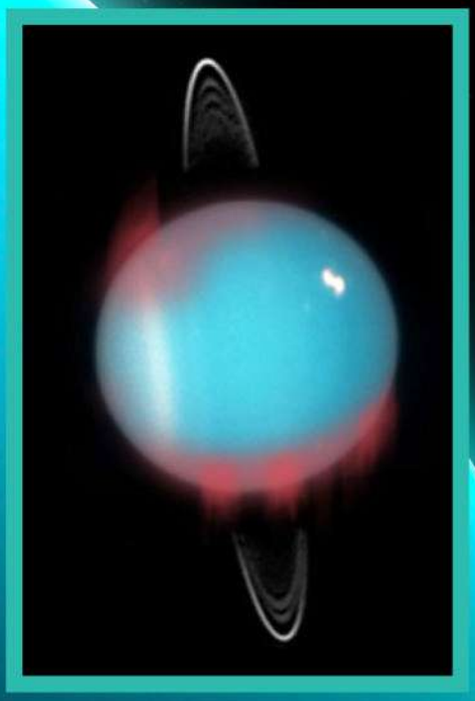
Reported by Keith Cooper

Astronomers using archived data from the giant Keck II telescope on Mauna Kea in Hawaii have successfully glimpsed Uranus' infrared aurora for the first time. Like aurorae on Earth, those on Uranus are caused when charged particles riding the solar wind interact with the planet's magnetic field and are funnelled along magnetic field lines towards the magnetic poles. As they enter Uranus' atmosphere, the charged particles collide with atmospheric molecules, causing those molecules to glow.

On Earth the auroral light comes from collisions with oxygen and nitrogen atoms, with the colours mostly red, green and blue. On Uranus, the dominant atmospheric gases are hydrogen and helium, which are at much lower temperatures than on Earth. These result in Uranus' auroral glow being predominantly at ultraviolet and infrared wavelengths. Ultraviolet aurorae on Uranus were first seen in 1986 by NASA's Voyager 2 probe, which flew past the planet that year. But it's taken nearly 40 years to detect the infrared counterpart.

Using data from the Keck II Near-Infrared Spectrometer (NIRSPEC) taken all the way back in 2006, astronomers led by graduate student Emma Thomas of the University of Leicester identified emission lines from the H_3^+ molecule. H_3^+ is a trihydrogen cation that contains three protons and only two electrons, meaning it's positively charged. The Uranus emission was the result of molecular hydrogen being ionised and forming H_3^+ cations following collisions with charged particles, with the emission creating an infrared auroral glow over the northern magnetic pole. In essence, Thomas' team saw Uranus' northern lights. "The temperatures of all the gas giant planets, including Uranus, are hundreds of degrees above what models predict if only warmed by the Sun, leaving us with the big question of how these planets are so much hotter than expected," said Thomas. "One theory suggests the energetic aurora is the cause of this, which generates and pushes heat from the aurora down towards the magnetic equator."

Another mystery that the aurorae could help solve is why Uranus and Neptune's magnetic fields are misaligned with their rotational axes by such a large amount – on Uranus the misalignment is 59 degrees. Because aurorae trace out the magnetic field structure of a planet, which is coupled to the upper layers of the atmosphere, further study could reveal hidden clues as to the origin of this misalignment.



> An artist's impression of the newfound infrared aurora superimposed on a Hubble photo of Uranus

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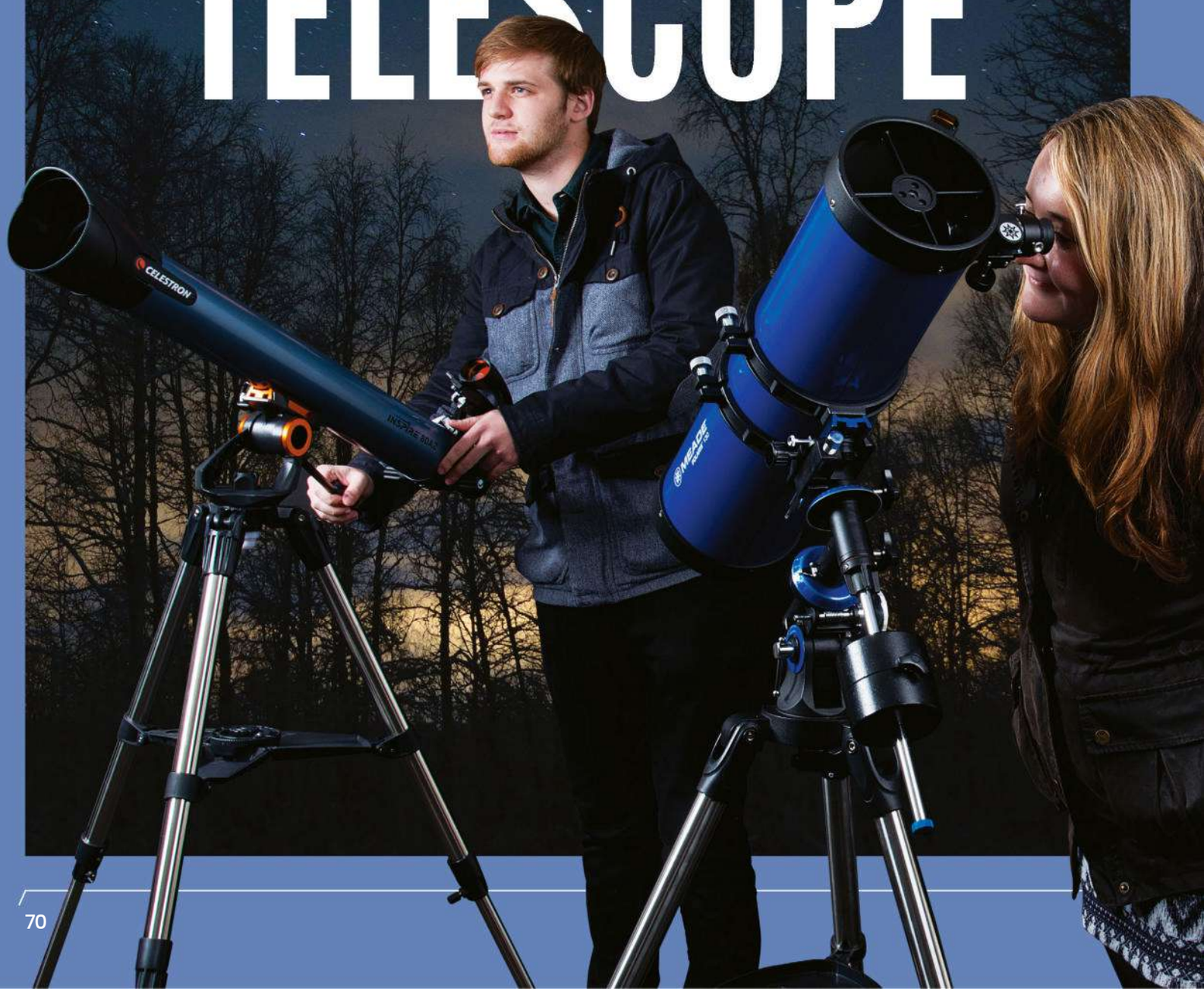
YOUR GUIDE TO THE PERFECT TELESCOPE

You've decided to buy a new instrument, but which one should you get?

Written by Stuart Atkinson



Even though you can see a lot of beautiful and amazing things in the night sky with just your naked eye or binoculars on a clear night, for most people, astronomy equals telescopes. Do a search for 'stargazing' and you'll be presented with countless images of wide-eyed, happy people looking into or standing next to telescopes, usually beneath a totally cloud-free sky dusted with stars. Magazines are full of adverts for telescopes, and astronomy websites and blogs are packed with accounts of how beautiful star clusters, galaxies and nebulae look through them. Naturally, every stargazer eventually reaches the point where they decide they want a telescope of their own so they can gaze upon the wonders of the universe. But there are so many telescopes to choose from... which one would be the perfect telescope for you? It's quite simple – the one you will actually use.

But how do you know in advance which telescope you will use? Just as you might do before buying a car, a house or even a new laptop, you have to ask yourself some questions, and answer them honestly. If you do that you'll learn that some telescopes will be too big and heavy for you to use, and some will not be powerful enough to let you see what you want to see. You'll realise that some telescopes will be too complicated to set up, and some will be too basic to meet your needs. You'll also realise that some telescopes are just way beyond your budget. When you've figured out what you really want to see through a telescope, where you will be using it, how much you can afford to pay for one and so forth, then you can make a decision. We're here to help you get to that point, because if you buy the wrong telescope for you it will probably put you off astronomy for good.

WHAT DO I NEED TO KNOW BEFORE CHOOSING A TELESCOPE?

What do I want to see through my telescope?
The Moon and planets? Or faint objects such as galaxies, clusters and nebulae?

Where do I want to use my telescope?
Away from home at a dark-sky site, or just from my garden?

Am I really ready for a telescope?
Do I know the night sky well enough to find what I'm looking for?

How much can I afford?
What is my budget for a telescope?

Do I want to take photographs through my telescope?
Or just use it visually?

> Extra eyepieces can be bought for a multitude of uses

THE REFLECTOR

These use a series of mirrors and are great for viewing distant galaxies and nebulae

Reflectors use mirrors instead of lenses. They are basically a tube, open at the front, with a large mirror mounted down the bottom end. Light from the night sky enters the tube, hits the mirror, reflects off it and is diverted out of the tube's side by a smaller secondary mirror, into a focusing eyepiece. Reflectors are probably the most popular type of telescope. Not just because they are a good general-purpose telescope, but because an entry-level reflector can be bought for a very reasonable sum. In fact, in terms of cost per inch of aperture, a reflector is definitely better value for money than a refractor.

Go to any dark-sky site and most telescopes in use there will be reflectors. This is because reflectors are very well suited for observing deep-sky objects. Because the objects they observe, such as distant galaxies and nebulae, are very far away and very faint, reflectors are perfect for observing them. They are essentially 'light buckets' that collect a lot of starlight with their wide mirrors. Under a truly dark sky, even an entry-level reflector will provide wonderful views of the gracefully curving arms of spiral galaxies and the misty blossoms of nebulae. These telescopes will still give pleasing views of Solar System objects, but their open tubes allow air to circulate inside, which reduces the sharpness of their images.

IS A REFLECTOR RIGHT FOR ME?

Large-aperture, good optical quality reflectors are now available at very reasonable prices

Popular telescope choice for observers wanting to enjoy viewing deep-sky objects such as galaxies and nebulae

Cradle-mounted 'Dobsonian' reflectors are very easy to assemble and use

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ANATOMY OF A REFLECTOR

1 Main mirror
Light is collected by this large mirror, mounted at the far end of the tube. Its position, shape and focus can all be finely adjusted with screws.

2 Finder telescope
This low-power telescope helps aim the main telescope at targets in the sky.

3 Front cover
Covering the open end of the tube prevents dust and damaging foreign objects falling down onto the mirror.

4 Telescope tube
Because their job is simply to hold a pair of mirrors in place, reflector tubes can be either enclosed or have an open framework.

5 Telescope mount
A Dobsonian's 'cradle' lets the tube move up and down and swing left and right, while more sophisticated mounts use motors to let the telescope track objects moving across the sky.

6 Focuser
This is mounted on the side of the main tube. As it slides in and out, moved using small wheels, an eyepiece slotted into it intercepts light reflecting off a small mirror mounted in the tube behind it.

7 Tripod
Some reflectors are supported on tripods. If the tripod is too light, the telescope image will wobble and shake, making the telescope useless. Poor-quality tripods can often be replaced with better ones.

IS A CATADIOPTRIC RIGHT FOR ME?

A combination of mirrors and lenses produces a 'best-of-both-worlds' instrument with the best features of some refractors and reflectors

Less image distortion than either refractors or reflectors

Telescopes that have the performance of a large aperture in a compact package

Lighter and more portable than a reflector of the same aperture

Popular telescope choice for observers wanting high-magnification views of all astronomical objects

Typically three times more expensive than reflectors of the same aperture

Less image contrast than refractors or reflectors when viewing closer objects

Can be hard to use to look at objects overhead due to the location of the eyepiece

NEWTONIAN VS DOBSONIAN

Which is right for me?

- You want a reflector that's easy to set up
- Requires an alt-azimuth mount
- Prefer to observe galaxies and nebulae

You should choose a Dobsonian

- Looking for a reflector with better optical performance than a refractor
- You Want to try out astrophotography
- Images free of false colour

You should choose a Newtonian

Cassegrains are mounted on top of their tripods in various ways. Some sit inside a fork-shaped cradle or an equatorial 'wedge', while others are mounted on a single arm with a computerised Go-To system

THE CATADIOPTRIC

A bit more costly, these combine the best bits of reflectors and refractors to give wonderful views

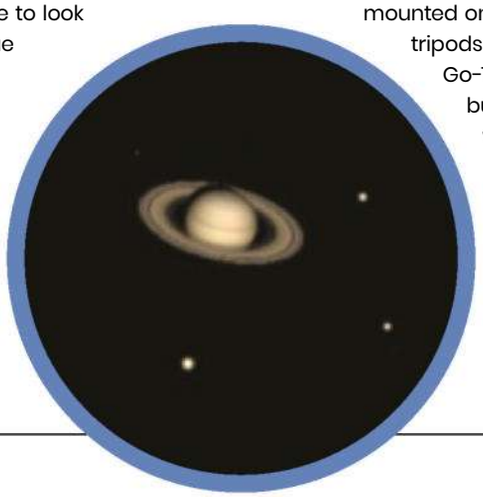
In effect, a catadioptric is a long, large-aperture reflector that has been squashed and scrunched up into a shorter, stubbier tube, with some lenses put in to make it perform even better. You can always easily spot a catadioptric at a star party or in a telescope shop. They look like shiny metal barrels, often coloured a striking metallic blue or orange, mounted on the top of very sturdy-looking tripods. And they're usually surrounded by a crowd of adoring stargazers. Catadioptrics are now the telescope of choice for many serious observers and astrophotographers. Their complicated optical systems mean that they suffer from less image distortion than either refractors or reflectors, and when packed away they take up less room in the back of a car than either a large refractor or reflector – useful for trips to dark skies.

However, catadioptrics aren't perfect. They're expensive – typically three times more expensive than reflectors of the same aperture – so the high-end models are beyond the budgets of most people wanting to buy their first telescope. Smaller, more modest models are available, but for the money they cost you might as well buy a larger refractor or reflector. They also offer views of very bright objects, such as the Moon, that have less contrast than refractors or reflectors. Like standard reflectors, they are more suitable for deep-sky observers than lunar observers.

Another potential problem for a catadioptric buyer to consider is that they can be hard to use to look at objects overhead due to the location of their focuser and eyepiece at the rear end of the tube. Looking at an object high in the sky through a catadioptric often means having to bend down, or sometimes even kneel on the ground, to look into the eyepiece. But catadioptric owners put up with that for the amazing views they enjoy through their telescopes.

There are two main types of catadioptric. The 'Schmidt-Cassegrain' is the most common type, and incorporates a large primary mirror, a smaller secondary mirror and a correcting plate lens. Light passes down the tube, through the corrector plate, reflects off the primary mirror and goes back up the tube, where it's reflected down again off the secondary mirror. The light then passes through a hole in the centre of the primary mirror into the telescope eyepiece. The 'Maksutov-Cassegrain' design is very similar in that it uses a combination of mirrors and lenses to collect light and form an image. However a Maksutov-Cassegrain uses a more highly curved corrector plate lens at the front of the tube to help focus the incoming light onto the main mirror. Like refractors, the optical qualities of Maksutovs make them more suitable for observing the Moon and Solar System objects than deep-sky objects.

All catadioptric telescopes are mounted on very sturdy tripods. Almost all are now Go-To telescopes with built-in computers, which once the telescope is properly aligned with the pole can be pointed at any object in the sky simply by selecting its name or details with a handset.



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SCHMIDT VS MAKSUTOV-CASSEGRAIN

Which is right for me?

- You want a low-maintenance telescope
- Portability is essential
- You want to observe Solar System and bright deep-sky objects

You should choose a Maksutov-Cassegrain

- You have a low budget
- Interested in observing all kinds of targets besides open clusters and large patches of the Milky Way
- Aren't bothered about purchasing corrector lenses to reduce coma
- Require portability

You should choose a Schmidt-Cassegrain

ANATOMY OF A CATADIOPTRIC

1 Focuser
Catadioptrics are focused by turning a small knob on the rear end of the tube instead of the small wheels and drawtube used by refractors and reflectors.

2 Finder telescope
This low-power telescope helps align the telescope with the celestial pole. As most catadioptrics are computerised Go-To telescopes, it's rarely used to help locate objects.

3 Eyepieces
Small cylinders fitted with lenses are used to focus the light diverted out of the main tube's rear. Different eyepieces provide high or low magnifications and narrow or wide fields of view.

4 Telescope tube
Tubes are short, compact and sturdy. They are often coloured metallic blue, orange or black. The tube holds the main mirror at the rear, a secondary mirror and correction plate.

5 Main mirror
Light is collected by this large mirror. Its position and shape can be adjusted with screws on the end of the tube to ensure good focus.

6 Front cover
Covering the front of the tube prevents the corrector plate becoming dusty or damaged when the telescope is being transported or assembled.

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YOUR SKYWATCHING QUESTIONS ANSWERED

What are magnification, aperture and focal length?

The larger a telescope's aperture – the size of its main lens or primary mirror – the more light is collected and more fine detail is revealed. Under ideal conditions, a 100mm telescope reveals stars down to magnitude +11.8, while a 200mm telescope will show stars down to magnitude +13.3. A 100mm telescope will 'split' a double star separated by 1.5 arcseconds, but a 200mm telescope resolves a double star separated by just 0.6 arcseconds. Resolution is limited by the telescope's optical quality and the steadiness of Earth's atmosphere.

Telescopic magnification depends on the telescope's focal length and the focal length of the eyepiece used. Magnification is calculated by dividing the telescope's focal length by the focal length of the eyepiece. For example, a 100mm telescope with a focal length of f/8 has a focal length of 800mm. Used in conjunction with an eyepiece of 10mm, it will deliver a magnification of 80 times. With any telescope, the range of useful magnification depends on aperture and focal length combined with the focal length of the eyepiece. Too low a magnification will waste light, since the 'exit pupil' of the eyepiece will be larger than the diameter of the pupil of your dark-adapted eye. Exit pupil can be calculated by dividing the telescope's aperture by the magnification delivered by any particular eyepiece.

How do different eyepieces work?

Eyepieces work by magnifying the light focused by the telescope's primary mirror or objective lens. Every eyepiece has a certain focal length, and the shorter this figure is, the higher the magnification. To calculate the magnification given by any eyepiece on any telescope, simply divide the telescope's focal length by the focal length of the eyepiece used. For example, a 1,000mm focal length telescope will deliver a magnification of 100x with a 10mm eyepiece.

Although any telescope is capable of giving impressively high magnifications using short-focal-length eyepieces, there's a point where increasing magnification will provide a worse image. When an object is magnified, its brightness is reduced as the finite amount of light coming from it is spread over a larger area. In addition, increasing magnification exacerbates the amount of atmospheric turbulence visible, and therefore high magnifications can only be used when seeing conditions are good. Finally, high magnifications are practical only with driven telescopes, otherwise the object will drift out of the field of view very quickly. As a guide, your highest power eyepiece should deliver a magnification that is double the telescope's aperture in millimetres – for example, 200x on a 100mm telescope, 400x on a 200mm telescope and so on.

What is a finderscope used for?

A finderscope is a low-power telescope that sits on your main telescope. Your main telescope will typically have a narrow field of view, meaning you'll see only a little portion of the sky when you look through it. Your finderscope, with a wider field of view, assists you in pointing your telescope to your desired subject, making it easy to hone in on your target with minimal searching. Centre your subject in the finderscope's frame, and when you look through your telescope's eyepiece your subject will be centred here too.

Many telescopes include a finderscope, but if you need to purchase one separately it's worth knowing there are two main types. One has a straight-through view, and one has a right-angled view. Generally, you'd want a right-angle finder if you have a Newtonian telescope and a straight-through if you use a refractor or catadioptric due to the location of their eyepieces. Some will also be magnified – higher magnifications and a narrower field may be desirable if you need pinpoint accuracy. You'll also come across the terms 'inverted' or 'erect image.' The latter means the finderscope has a correcting prism that flips the image. Some finderscopes don't have a correcting prism, so you see either a back-to-front image or an upside-down one, which might be disorientating and make finding subjects more difficult.

THE REFRACTOR

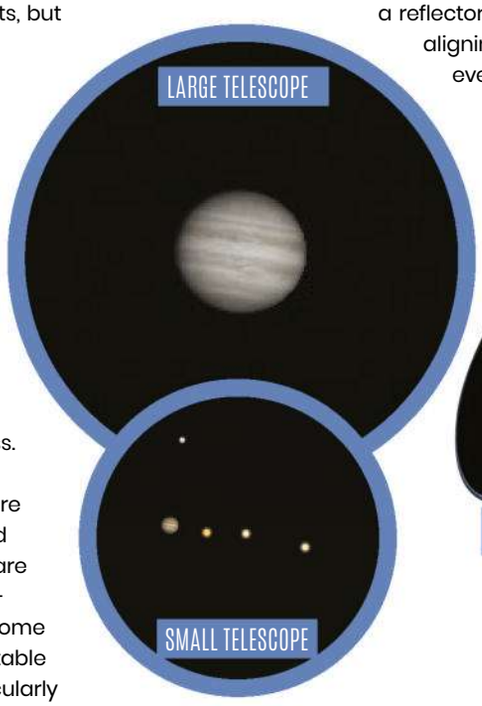
The original telescope, perfect for viewing details on 'close-by' Solar System objects

A refractor is essentially a tube with lenses at either end which work together to make faraway objects appear closer. High-quality refractors remain the popular telescope for astronomers wanting to enjoy detailed views of the Moon and planets. Refractors perform so well on these objects because their tubes are closed, which means less air moving about inside them and less distortion of images visible through them.

When purchasing a refractor, it's important to buy the best you can afford. The cheapest refractors have poor-quality lenses, which are often badly aligned, too. This results in images with distortion around the edges and coloured fringes, which you want to avoid. Refractors with the best quality lenses are very expensive compared to reflectors, but you really do get what you pay for. If you want to enjoy crisp, detailed views of Saturn's rings, the cloud systems of Jupiter and the surface features of Mars, then a refractor is the telescope for you. It will provide much better views of those objects than a reflector of equal, or even larger, aperture. However, refractors do not perform as well as reflectors when turned towards the 'faint fuzzies', such as galaxies and nebulae. If you are wanting to observe famous objects such as the Andromeda Galaxy and the Orion Nebula, then a refractor might not be your best choice.

Modern refractors come on a wide variety of mounts, but it's important to note that all refractors are supported by tripods. As with any telescope, it's important to pick a refractor mounted on a stable, steady tripod or the image you see looking through it will jump around so much it will be useless. Many of the 'budget' refractors available are actually of quite good quality optically, but are let down by the poor-quality tripods they come supplied with. Small 'table top' tripods are particularly useless, and telescopes that come with those are little better than toys. However, a budget refractor's poor tripod can often be replaced with a good photographic tripod.

Refractors on simple alt-azimuth mounts are essentially 'point-and-look' telescopes – you just move the tube up and down and from side to side until it's pointed roughly towards what you want to look at, then align the telescope more accurately using a small 'finderscope' mounted on the main tube. More complicated mounts allow you to find objects in the sky by first aligning the telescope with the Pole Star and then turning dials on the mount until the telescope is pointed at a specific set of coordinates in the sky. Many modern refractors are mounted on computerised Go-To mounts, which make them very easy to use. After aligning the telescope on the Pole Star and then on several additional 'guide stars', you enter the date and your location into the computer, then select an object from the telescope's own database by scrolling through various menus. The telescope then finds that object in the sky for you, slewing around until it is centred in its eyepiece. Entry-level refractors are easy to assemble and maintain. Unlike a reflector, refractors don't need aligning or collimating before every use.



ACHROMATIC VS APOCHROMATIC

Which is right for me?

- Want a simple telescope to use
- Have a low budget for a small aperture
- Want a low-maintenance telescope
- Can tolerate the colour fringing of cheaper achromatics
- Enjoy views of the Solar System

You should choose an achromatic

- Would prefer a refractor that doesn't suffer from colour fringing
- Have a high budget
- Enjoy views of the Solar System
- Are happy to own a high-maintenance telescope

You should choose an apochromatic

IS A REFRACTOR RIGHT FOR ME?

Small-aperture, good optical quality refractors are available at very reasonable prices

Popular telescope choice for observers wanting to enjoy detailed views of the Moon and planets

Small refractors can be easy to assemble and use

Unlike reflectors, refractors do not invert or reverse their views, which is less confusing for a beginner

ANATOMY OF A REFRACTOR

1 Objective lens
Light is gathered by this main lens, mounted at the front, then focused through an eyepiece at the other end of the tube. Typically, the larger this lens is, the more expensive the refractor will be.

2 Lens cover
This cover might not look very important, but it protects the main lens from dust and damage while the telescope is being stored or assembled.

3 Telescope tube
The telescope's lenses are mounted securely in this long tube. It is coated with dark material to prevent reflections which would spoil the image. The tube fits into a mount on top of a tripod.

4 Telescope mount
Mounts can be very simple or very complicated. The simplest just let the tube move up and down and swing left and right. High-tech Go-To mounts use an onboard computer to steer the telescope towards objects.

5 Tripod
This supports the telescope and should be sturdy, strong and very steady. If it wobbles, the telescope image will shudder and shake too, making the telescope useless.

6 Eyepieces
Small, cylindrical eyepieces fitted with lenses are used to focus the light sent down the tube by the main lens. Different eyepieces provide different magnifications and fields of view.

7 Finder telescope
This helps you find objects in the sky. If it is aligned properly with the main telescope, objects placed in the centre of this low-power telescope's field of view should be visible in the main telescope's eyepiece too.

I CAN'T SEE ANYTHING THROUGH MY TELESCOPE

Your telescope might not be collimated properly

When a telescope is collimated properly, all of the instrument's mirrors or lenses are aligned. When they are not lined up, then light from the object you're looking at can't be reflected or refracted in such a way that you can see the object.

SOLUTION: Schmidt-Cassegrain telescopes and reflectors can be collimated by yourself with ease. However, unless you're an optical expert, we wouldn't advise trying to align the lenses in a refractor telescope. Remember, if you're unsure of how to collimate your instrument, take it to an expert who knows how.

You might not be dark-adapted

You can see some brighter night sky targets as soon as you head out, and even under moderate light-polluted skies, but it's not true for fainter stars, planets and deep-sky objects, even if you are looking at them through your telescope.

SOLUTION: You should wait for your eyes to adapt to the dark before trying again. This usually takes around 20 minutes. Ensure that if you need to use a torch that it emits red light rather than white.

Your telescope might not be aimed at anything

You might find your telescope isn't pointing at anything in particular other than a patch of dark sky, devoid of any bright objects.

SOLUTION: Simply make sure you're pointing your telescope at a bright target, at the very least to check if there isn't something more serious afoot. A good example of one is the Moon if it's out on the night you've chosen to do your observations.

TELESCOPE TROUBLESHOOTING

I can't find anything using my telescope

SOLUTION: If you don't own a Go-To to help you find objects with ease, then you should use your telescope's guide scope or finderscope, provided that this has also been aligned correctly. You can also look along the end of your instrument's tube to get an idea of how it should be aligned in order to view your chosen target. Looking at the Moon at your telescope's lowest magnification is your best bet at solving this problem.

Why does my target keep moving out of view?

SOLUTION: Telescopes from supermarkets or catalogues often suffer from poor mounting. If tightening your mount doesn't work, then replacing it with a mount that's capable of holding your telescope's tube is an option.

Everything looks blurry

SOLUTION: The first thing that you should do is check and adjust the focuser of your telescope to see if you can bring the object into focus. If this doesn't seem to be working, then it could be that your optics are dirty, so ensure that your eyepiece is clean. If you have cleaned your optics carefully, then it could be that the eyepiece that you're using is defective, so try and use a good well-known eyepiece to see if that fixes the problem.

Some bright objects have coloured fringes

SOLUTION: Colour-fringing cannot be reduced when you're observing through a telescope. The good news is that you can remove chromatic aberration in Photoshop if you're an astrophotographer. If it's something that you feel bothers you, either go for an apochromatic refractor, reflector or Schmidt-Cassegrain.

I can't get the entire field of view into focus

SOLUTION: The only real cure is to replace your telescope's mirror. If you have purchased a brand-new telescope and it is suffering from spherical aberration, then you should return the instrument and ask for a refund.

Stars change shape or grow tails when I bring them into focus

SOLUTION: You can often buy accessories to correct coma, but you might find that these are quite expensive. If you own a reflector then you should check that nothing is pushing down on your instrument's mirrors. Alternatively, if the astigmatism is severe, you should replace the troublesome component. If your instrument is new then you should return it and ask for a refund from the dealer.

I can see 'ghosting'

SOLUTION: It could be that your eyepieces don't have anti-reflection coatings, so you should use better eyepieces. Manufacturers of cheap 'toy' telescopes often don't paint the inside of the tube black. In this case, you're better off purchasing a telescope of higher quality.

"Some telescopes will be too big and heavy for you to use, and some will not be powerful enough to let you see what you want to see"

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WHAT'S IN THE SKY?

What to look out for during this observing period

In this issue...

80 What's in the sky? Wrap up warm for those long, cold nights of winter observing

82 Planetarium Where you can find the planets this month and the phases of the Moon

84 Month's planets Most of the Solar System's planets will be visible in the evening, while Venus is a dazzling morning object

86 Moon tour Even at its lesser phase, our natural satellite is worth looking at in its own right

87 Naked eye and binocular targets Brave the cold and find some of the wonders waiting for you among the stars of Taurus

88 Deep sky challenge Track down some lesser known wonders on the next clear and frosty night

90 The Northern Hemisphere There's an impressive array of targets to enjoy, including galaxies, nebulae and vibrant double stars

92 Review We put the Canon EOS Ra camera to the test

96 In the shops Our pick of the best gifts and accessories for astronomy and space fans

4 DECEMBER
Mercury is at its greatest separation from the Sun in the morning sky at -0.5

6 DECEMBER
Neptune reaches the end of its retrograde motion

6 DECEMBER
The December Phi Cassiopeid meteor shower reaches its peak

9 DECEMBER
The December Monocerotid meteor shower reaches its peak

9 DECEMBER
The Moon and Venus make a close approach, within 3°18' of each other in Virgo

10 DECEMBER
Mercury is at its greatest altitude in the evening sky, shining at magnitude -0.5

"The Moon and Saturn make a close approach, within 2°15' of each other in Aquarius"

14 DECEMBER
The Geminid meteor shower reaches its peak

16 DECEMBER
The Comae Berenicid meteor shower reaches its peak

19 DECEMBER
The Moon will pass in front of Neptune in a lunar occultation from Western Australia

21 DECEMBER
Asteroid 4 Vesta reaches opposition in Orion, glowing at magnitude +6.4

22 DECEMBER
The Moon and Jupiter make a close approach, passing within 2°22' of each other in Aries

22 DECEMBER
Asteroid 9 Metis reaches opposition in Gemini, glowing at magnitude +8.4

22 DECEMBER
The Moon and the Pleiades pass within 57.2' of each other in Taurus

Naked eye | Naked eye warning (TAKE CARE!) | Binoculars | Small telescope | Medium telescope | Large telescope | Solar eclipse | Solstice

8 DECEMBER

Mercury reaches half phase in the evening sky, shining brightly at -0.3

12 DECEMBER

The Sigma Hydrid meteor shower reaches its peak

15 DECEMBER

The Running Man Nebula (NGC 1977) is well placed in Orion

17 DECEMBER

The Moon and Saturn make a close approach, within 2°15' of each other in Aquarius

20 DECEMBER

The December Leonis Minorid meteor shower reaches its peak

21 DECEMBER

December solstice

Red-light friendly

In order to preserve your night vision, you should read our observing guide under red light

26 DECEMBER

The Moon will pass in front of Beta Tauri, creating a lunar occultation visible from Argentina, southern Brazil, Uruguay and the eastern Falkland Islands, among others

28 DECEMBER

Asteroid 5 Astraea reaches opposition in Orion, glowing at magnitude +9.4

Jargon buster

Conjunction

An alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Declination (Dec)

How high an object will rise in the sky. Like Earth's latitude, Dec measures north and south in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and 60 arcminutes in a degree.

Opposition

When a celestial body is in line with Earth and the Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Right Ascension (RA)

RA is to the sky what longitude is to Earth, corresponding to east and west. It's measured in hours, minutes and seconds, as since Earth rotates on its axis we see different parts of the sky throughout the night.

Magnitude

An object's magnitude tells you how bright it appears from Earth, represented on a numbered scale. The lower the number, the brighter the object. A magnitude of -1.0 is brighter than +2.0.

Greatest elongation

When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongation and as morning stars during western elongation.

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PLANETARIUM

14 DECEMBER 2023

OPPOSITION

EVENING SKY

MOON CALENDAR

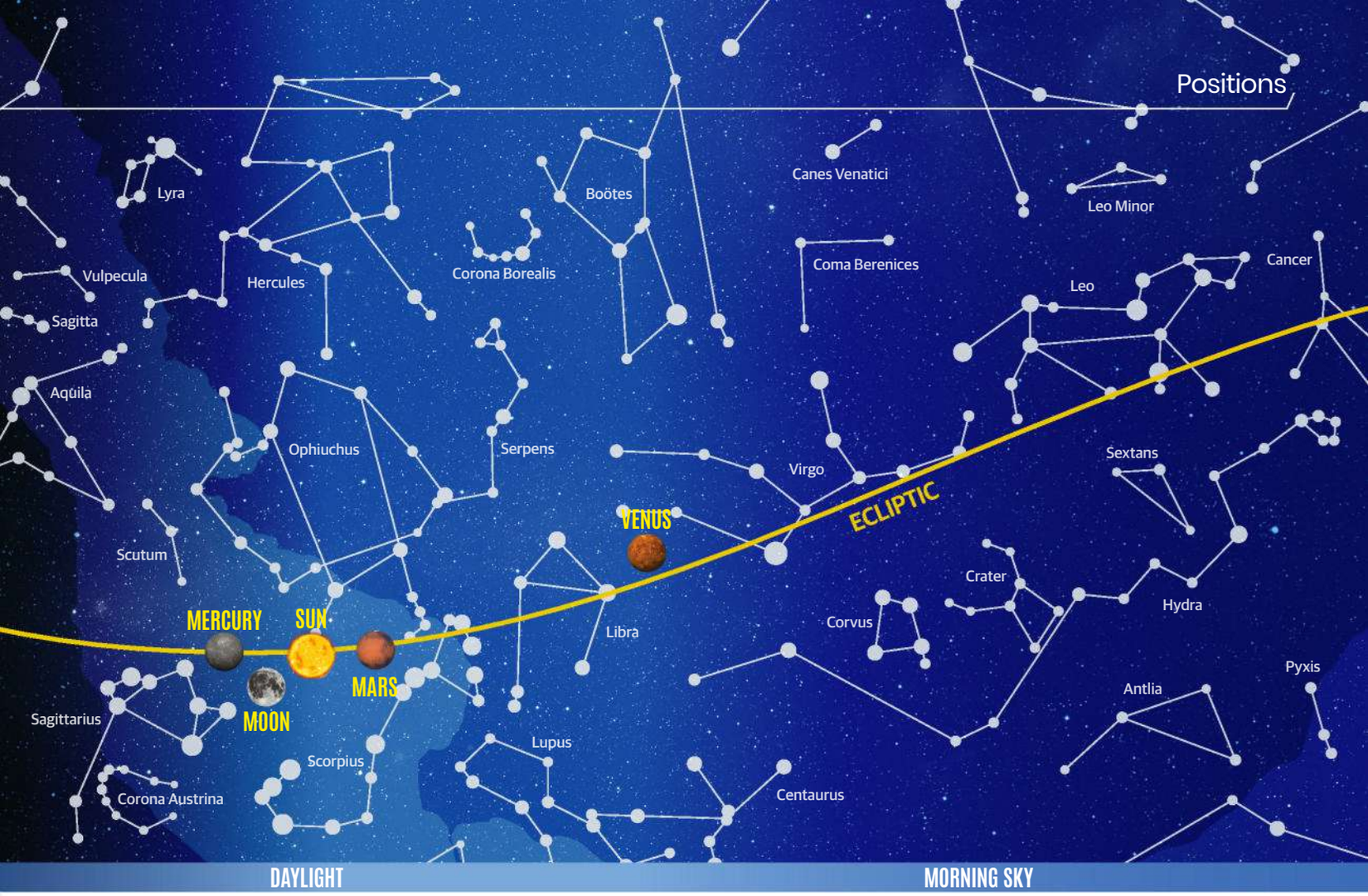
* The Moon does not pass the meridian on 26 December

30 NOV 91.9% 11:15 18:07	1 DEC 85.5% 11:51 19:18	2 DEC 77.7% 12:16 20:33	3 DEC 69.0% 12:35 21:46			
4 DEC 59.6% 12:48 22:58	5 DEC TQ 50.0% 13:00 --:--	6 DEC 40.4% 00:08 13:10	7 DEC 31.0% 01:18 13:20	8 DEC 22.1% 02:29 13:31	9 DEC 14.3% 03:44 13:43	10 DEC 7.7% 05:02 13:59
11 DEC 2.9% 06:24 14:21	12 DEC NM 0.4% 07:47 14:54	13 DEC 0.5% 09:04 15:42	14 DEC 3.4% 10:07 16:49	15 DEC 9.0% 10:52 18:13	16 DEC 17.1% 11:23 19:43	17 DEC 27.0% 11:45 21:13
18 DEC 38.1% 12:01 22:40	19 DEC FQ 49.8% 12:15 --:--	20 DEC 61.4% 00:04 12:27	21 DEC 72.2% 01:27 12:40	22 DEC 81.7% 02:51 12:54	23 DEC 89.5% 04:15 13:11	24 DEC 95.2% 05:39 13:35
25 DEC 98.7% 06:59 14:07	26 DEC --.-%* 08:10 14:52	27 DEC FM 99.8% 09:07 15:51	28 DEC 98.8% 09:49 17:00			

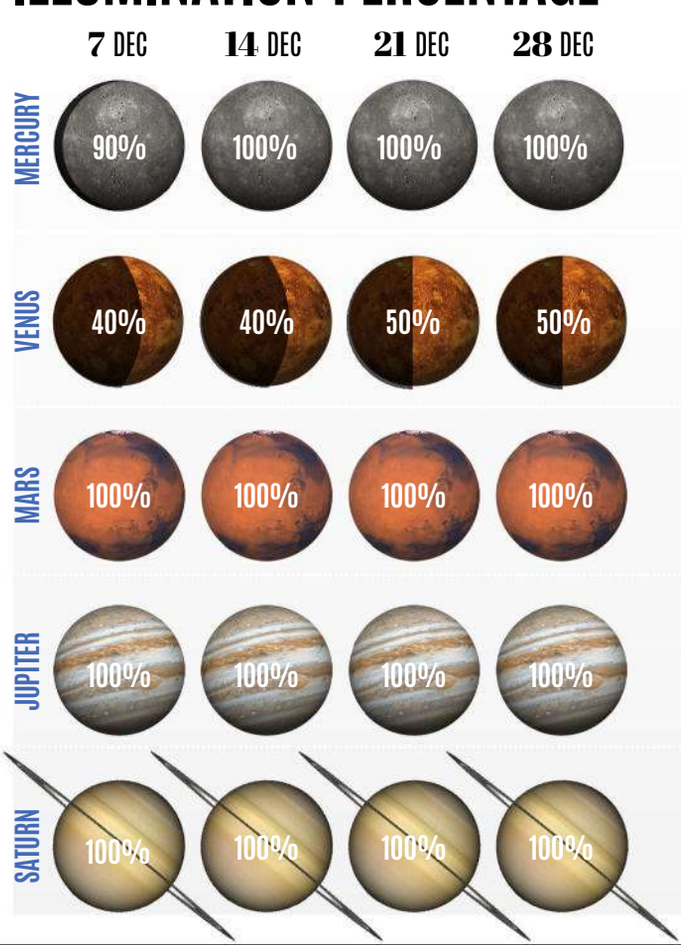
% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
TQ Third quarter

All figures are given for 00h at midnight (local times for London, UK)



ILLUMINATION PERCENTAGE



PLANET POSITIONS

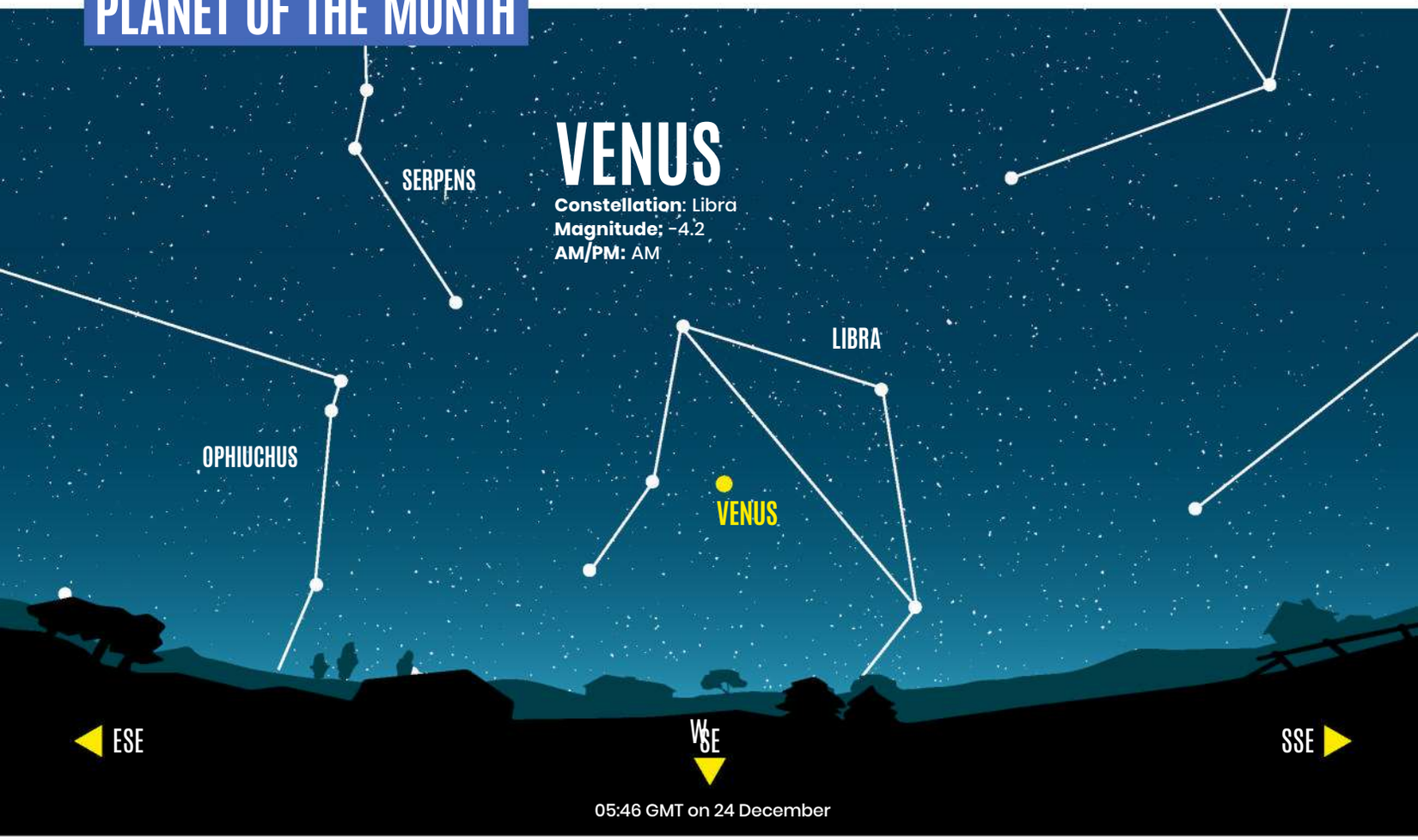
All rise and set times are given in GMT

DATE	RA	DEC	CONSTELLATION	MAG	RISE	SET
30 NOV	17h 55m 18s	−25° 50' 59"	Sagittarius	−0.5	09:41	16:48
7 DEC	18h 26m 36s	−25°07'57"	Sagittarius	−0.4	09:43	16:58
14 DEC	18h 34m 27s	−23°31'08"	Sagittarius	+0.8	09:16	16:54
21 DEC	18h 06m 02s	−21°30'19"	Sagittarius	+5.4	08:11	16:17
28 DEC	17h 31m 19s	−20°09'48"	Ophiuchus	+1.5	06:57	15:22
30 NOV	13h 27m 55s	−06° 56' 58"	Virgo	−4.2	03:27	14:27
7 DEC	14h 08m 01s	−10° 33' 01"	Virgo	−4.1	03:50	14:13
14 DEC	14h 40m 12s	−13° 13' 05"	Libra	−4.1	04:09	14:02
21 DEC	15h 13m 20s	−15° 40' 58"	Libra	−4.1	04:29	13:54
28 DEC	15h 47m 28s	−17° 52' 07"	Libra	−4.1	04:48	13:47
30 NOV	16h 09m 21s	−21° 15' 03"	Scorpius	+1.4	07:24	15:39
7 DEC	16h 30m 41s	−22° 10' 00"	Ophiuchus	+1.4	07:24	15:26
14 DEC	16h 52m 27s	−22° 54' 50"	Ophiuchus	+1.4	07:23	15:15
21 DEC	17h 14m 35s	−23° 28' 46"	Ophiuchus	+1.4	07:22	15:05
28 DEC	17h 37m 02s	−23° 51' 10"	Ophiuchus	+1.4	07:20	14:57
30 NOV	02h 19m 32s	+12° 30' 49"	Aries	−2.9	14:34	04:53
7 DEC	02h 17m 08s	+12° 20' 31"	Aries	−2.8	14:05	04:22
14 DEC	02h 16m 49s	−12° 27' 33"	Aries	−2.7	13:36	03:52
21 DEC	02h 14m 04s	+12° 09' 04"	Aries	−2.7	13:08	03:22
28 DEC	02h 13m 30s	+12° 08' 22"	Aries	−2.6	12:39	02:54
30 NOV	22h 13m 50s	−12° 45' 47"	Aquarius	+0.9	12:41	22:35
7 DEC	22h 15m 11s	−12° 37' 27"	Aquarius	+0.9	12:14	22:09
14 DEC	22h 12m 03s	−12° 57' 23"	Aquarius	+0.9	11:47	21:44
21 DEC	22h 18m 42s	−12° 16' 09"	Aquarius	+0.9	11:20	21:19
28 DEC	22h 20m 51s	−12° 03' 24"	Aquarius	+0.9	10:54	20:55

THIS MONTH'S PLANETS

Most of the Solar System's planets will be visible in the evening, while Venus is a dazzling morning object

PLANET OF THE MONTH

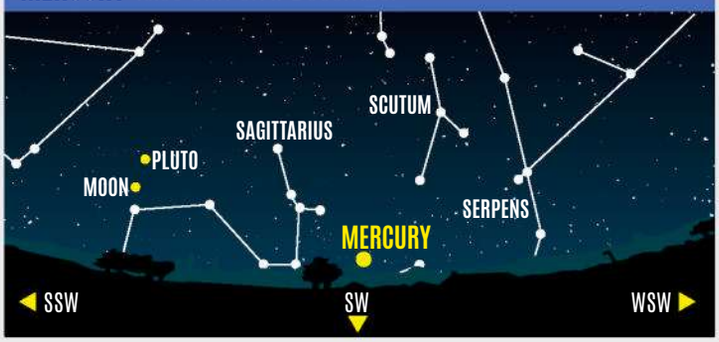


Venus is widely known as the 'evening star', because it's often seen shining brilliantly in the west after sunset. However, it is just as often visible in the morning sky before sunrise, and that's the case this coming month. All through December, through the festive celebrations and into the New Year beyond them, Venus will be a dazzling 'morning star'. Venus will be the brightest, most striking point of light in the morning sky, putting every other star and planet to shame with its brilliance. At the end of November Venus will be rising four hours before the Sun, giving you plenty of time to enjoy seeing it before the sky begins to brighten with the approach of dawn. By Christmas morning Venus will have moved from Virgo into neighbouring Libra and will have faded a little, but will still be rising three hours before the Sun, so you'll be able to take a moment's peace to appreciate its beauty if you head out for a walk before the present-opening madness begins.

In early December Venus will have some company in the sky. If you're up in the early hours on 8 December you'll see a lovely waning crescent Moon shining to Venus' upper right. The following morning, the Moon, now an even thinner crescent, will be just to the lower right of Venus, and the morning after that the fingernail-clipping-thin crescent Moon will be shining to the lower left of Venus. On all of these mornings the celestial pair will be a striking sight to the naked eye, a lovely sight in binoculars and bright enough to photograph using just the camera on your phone.

Venus is named after the goddess of love because it is so beautiful in the sky. It's also often referred to as 'Earth's twin', but while they are a similar size, that's a very misleading nickname because the two worlds could not be less alike. Where Earth is a lush, green-and-blue world teeming with life, Venus is a hellish planet with a curdled, poisonous carbon dioxide atmosphere and a barren landscape covered with plates of barren rock, where the pressures and temperatures are so high that no life is possible. The few space probes that landed on Venus didn't last long, and any astronauts brave enough to visit Venus in the future will have to wear spacesuits resembling suits of armour if they're going to last longer than a few minutes on its desolate, furnace-hot surface.

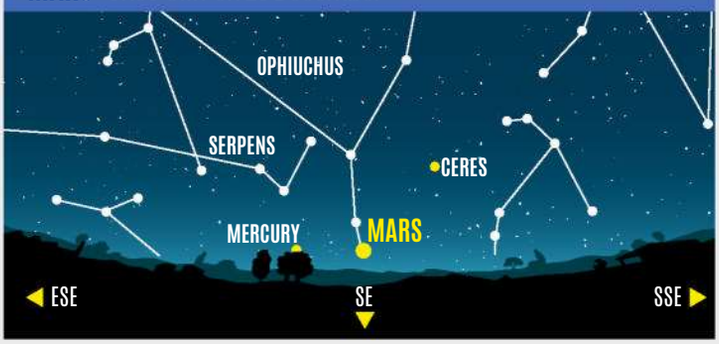
MERCURY 16:30 GMT on 17 December



Constellation: Sagittarius **Magnitude:** +0.4 **AM/PM:** PM

Mercury is the closest planet to the Sun, so it can only ever be seen close to it in the sky, too, glinting in the twilight before sunrise or after sunset. This month Mercury will be in the evening sky, but will be so close to the Sun it will effectively set at the same time, so it won't be visible.

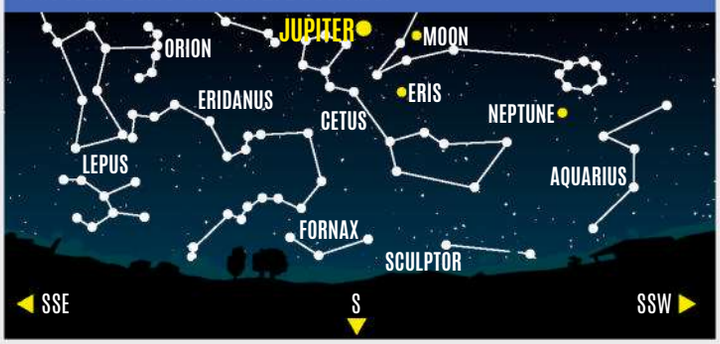
MARS 07:30 GMT on 25 December



Constellation: Scorpius **Magnitude:** +1.4 **AM/PM:** AM

At the end of November Mars, famously known as the Red Planet because of its ruddy hue to the naked eye in a clear sky, will be too close to the rising Sun to be visible. As the mornings pass it will slowly pull away from the Sun, and by Christmas Day it will be rising half an hour before the Sun clears the horizon.

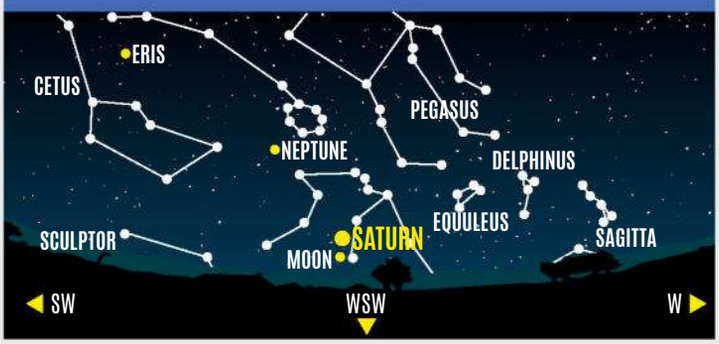
JUPITER 20:30 GMT on 21 December



Constellation: Aries **Magnitude:** -2.8 **AM/PM:** PM

As November ends, Jupiter will already be shining above the eastern horizon as the Sun sets, clearly visible to the naked eye even before the sky is properly dark. It will be at its best around 22:00, when it will be high in the south, visible all through the night. At the end of December Jupiter will still be dominating the evening sky.

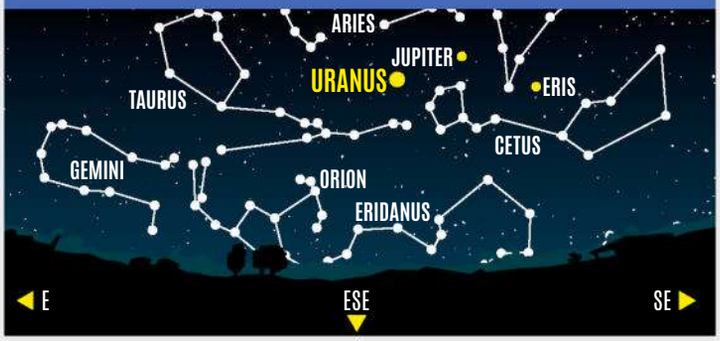
SATURN 20:30 GMT on 17 December



Constellation: Aquarius **Magnitude:** 0.9 **AM/PM:** PM

As November ends Saturn will already be visible to the naked eye as a 'star' low in the southeast. It will reach its highest point above the horizon at around 18:00 and will set by 23:00. Look out for the crescent Moon shining to the lower right of Saturn after dark on 17 December, and to its upper left the following evening.

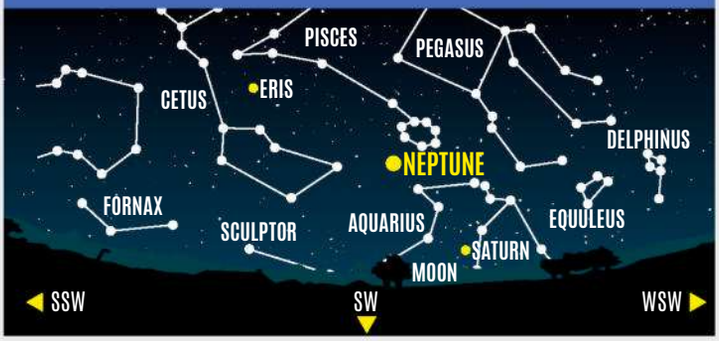
URANUS 19:00 GMT on 9 December



Constellation: Aries **Magnitude:** 5.6 **AM/PM:** PM

Uranus will be close to bright Jupiter this month, so if you slowly sweep your binoculars away from Jupiter, moving left, you'll soon see a green-hued star, and that will be Uranus. During our observing period Uranus will be visible from just after sunset right through the night, setting in the early hours.

NEPTUNE 20:31 GMT on 17 December



Constellation: Aquarius **Magnitude:** 7.9 **AM/PM:** PM

This month Neptune will shine quite close to much brighter Saturn in the sky in Aquarius. It will already be high in the southeast after sunset and will set around midnight, so you won't have long to try and track it down. The first quarter Moon will be shining close to Neptune on the evening of 9 December, to its upper left.

MOON TOUR

THE LAST QUARTER MOON

Even at its lesser phase, our natural satellite is worth looking at in its own right

This month our Moon tour doesn't have one specific destination. Instead we're going on a sightseeing cruise around the most striking features visible on the Moon after it rises around midnight on 5 December.

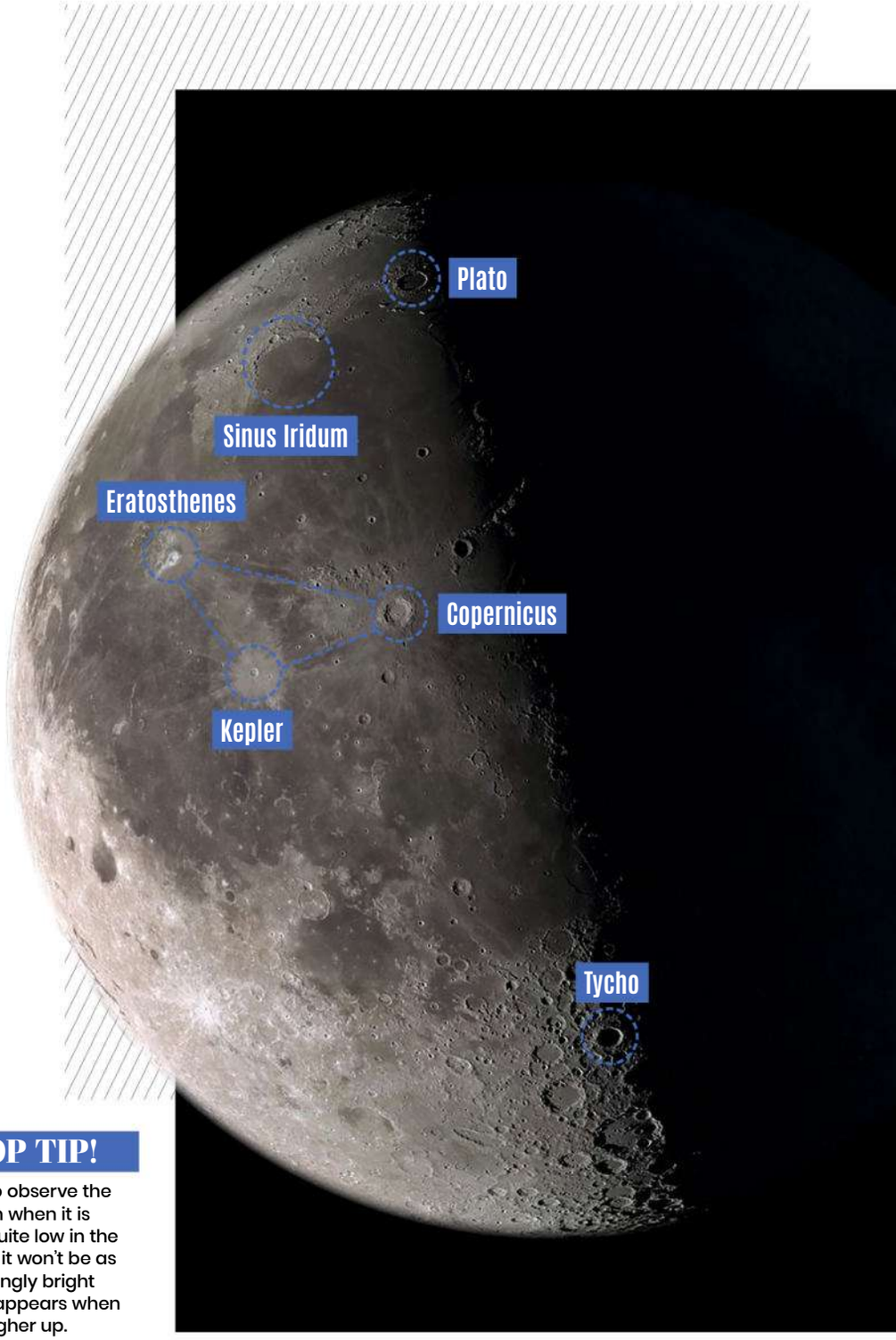
Once the Moon is clear of the horizon, you'll see that the illuminated half is light in some places and dark in others. The light areas are the so-called lunar highlands. These are rugged, mountainous areas dominated by jagged peaks and the deep valleys between them. They are made of very old lunar rock, and appear so bright to us here on Earth because they reflect a lot of sunlight. In contrast, the dark areas are flat, low and reflect much less sunlight. These dark areas are the famous 'seas', or mare, and they are actually vast plains of ancient, frozen lava.

Through binoculars or small telescopes you'll see a small triangle of bright spots on the illuminated part of the disc. Each of these is actually a huge crater blasted out of the Moon by the impact of a massive piece of space rock many millions of years ago. Look more closely and you'll see webs of bright lines surround these spots. These are rays of fine dusty and rocky debris that were blasted out of the Moon in the impact, sprayed away and then fell to the ground again, leaving bright streaks on the surface.

The crater at the top of the triangle is Eratosthenes, one of the youngest and brightest craters on the Moon. Some 59 kilometres (36.6 miles) wide and almost four kilometres (2.4 miles) deep, it's a lot brighter on its left. The middle crater in the triangle is Kepler, and its rays stretch for more than 300 kilometres (186 miles). To Kepler's right is Copernicus, the 'Monarch of the Moon', a huge crater 93 kilometres (57.7 miles) from side to side and almost four kilometres (2.4 miles) deep. It was formed more than 800 million years ago by a huge asteroid striking the Moon.

Look to the bottom of the Moon and you'll see another bright crater just to the left of the terminator – the line between lunar day and night. This is Tycho, another young crater surrounded by rays, formed only 100 million years or so ago. Look to the top of the Moon now and you'll see a small, strikingly dark oval close to the terminator. This is the crater Plato. It appears so dark because its floor is flat and covered in dark, ancient lava.

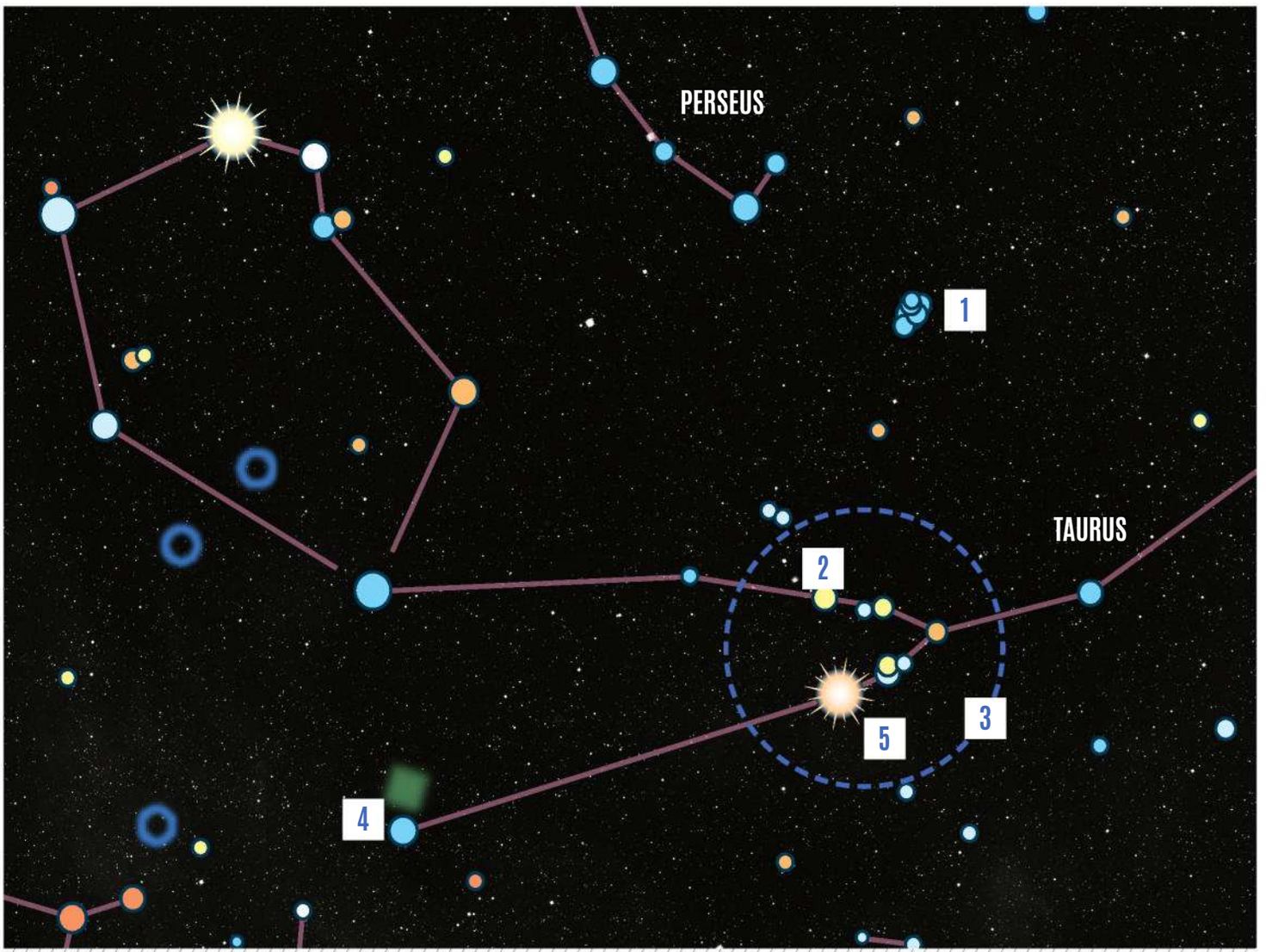
Look a short distance to Plato's left you'll see what looks like a semi-circular bay cut out of the bright surface of the Moon. This is Sinus Iridum, the Bay of Rainbows, and it's the surviving half of a crater that was flooded by lava many millions of years ago. It's considered to be one of the most beautiful landscape features on the Moon.



© NASA

TOP TIP!

Try to observe the Moon when it is still quite low in the sky – it won't be as blindingly bright as it appears when it's higher up.



NAKED EYE AND BINOCULAR TARGETS

Brave the cold and find some of the wonders waiting for you among the stars of Taurus

1 The Pleiades (Messier 45)

One of the prettiest and brightest star clusters in the sky, Messier 45 is also known as the Pleiades, or the 'Seven Sisters', because seven of its 500 or so stars can be seen with the naked eye. It appears wider than four Moons in our sky and lies 430 light years from Earth.

2 Ain (Epsilon Tauri) and Amateru (Epsilon Tauri b)

Shining close to Aldebaran, magnitude +3.5 orange giant star Ain is a member of the Hyades cluster. Almost 150 light years from Earth, it is orbited by a massive exoplanet that dwarfs Jupiter. Discovered in 2007, the planet was christened 'Amateru' in 2015.

3 The Hyades

The distinctive V-shaped Hyades star cluster has five stars bright enough to be seen with the naked eye, but actually contains between 300 and 400 members. It has been known since prehistoric times and can be seen on cave paintings many thousands of years old.

4 Crab Nebula (Messier 1)

The ghostly remains of a giant star that exploded in a massive supernova explosion in 1054, Messier 1 was nicknamed the Crab Nebula because of its appearance through a telescope. Too faint for the naked eye to see, it's best viewable through binoculars as a tiny smudge.

5 Aldebaran (Alpha Tauri)

This star is the 14th-brightest in the sky. An orange giant star 44 times our Sun's diameter, it lies 66.6 light years from Earth and represents the eye of Taurus, the Bull. Despite appearances, it's not a member of the Hyades cluster.

Canis Major constellation

DEEP SKY CHALLENGE

THE TWINS' SECRET TREASURES

Track down some lesser known wonders on the next clear and frosty night

As you set up your telescope on freezing cold December nights, it's always tempting to look at the same things you always do: the misty, swirling veils of the Orion Nebula, the Pleiades cluster with its stars sparkling like jewels and the Crab Nebula's ghostly haze all call out to you through your favourite eyepiece. But there is much more to the winter sky than those 'celebrity' objects, and if you swing your ice-cold telescope tube towards the constellation of Gemini, put in a high-power eyepiece and go deep – very deep – you can see some lesser known objects that deserve your attention just as much as their more famous neighbours.

Gemini is dominated by the open star cluster Messier 35, one of winter's showcase objects, and it's a beautiful sight in anything from a humble binocular to a huge Dobsonian. Scattered around it are much fainter, much more distant objects that are real treats once tracked down. The Eskimo Nebula (NGC 2392) – sometimes known as the Clown Face Nebula – is a lovely, intriguing planetary nebula that shows fascinating detail and structure through a large telescope, while the Twinkling Comet Cluster (NGC 2420) and spiral galaxy NGC 2339, which rests more than 250 million light years away, are also worthwhile targets to seek out with your telescope.

6 NGC 2266

"Under perfect conditions you will see hints of its tightly wound spiral arms"

1 NGC 2435

This intermediate spiral galaxy, sitting almost edge-on to us, is 200 million light years away. Measuring just 15 arcminutes across and shining at a very faint 13th magnitude, it is a challenge in even a large telescope.

2 THE TWINKLING COMET CLUSTER (NGC 2420)

This eighth-magnitude cluster looks nothing like a comet; it is more of a loose spray of stars in the centre of a keystone of four brighter stars.

3 THE ESKIMO NEBULA (NGC 2392)

In a large telescope's high-power eyepiece, this ninth-magnitude planetary nebula really does look like a face surrounded by a hood... but Eskimo or clown? You decide.

4 NGC 2331

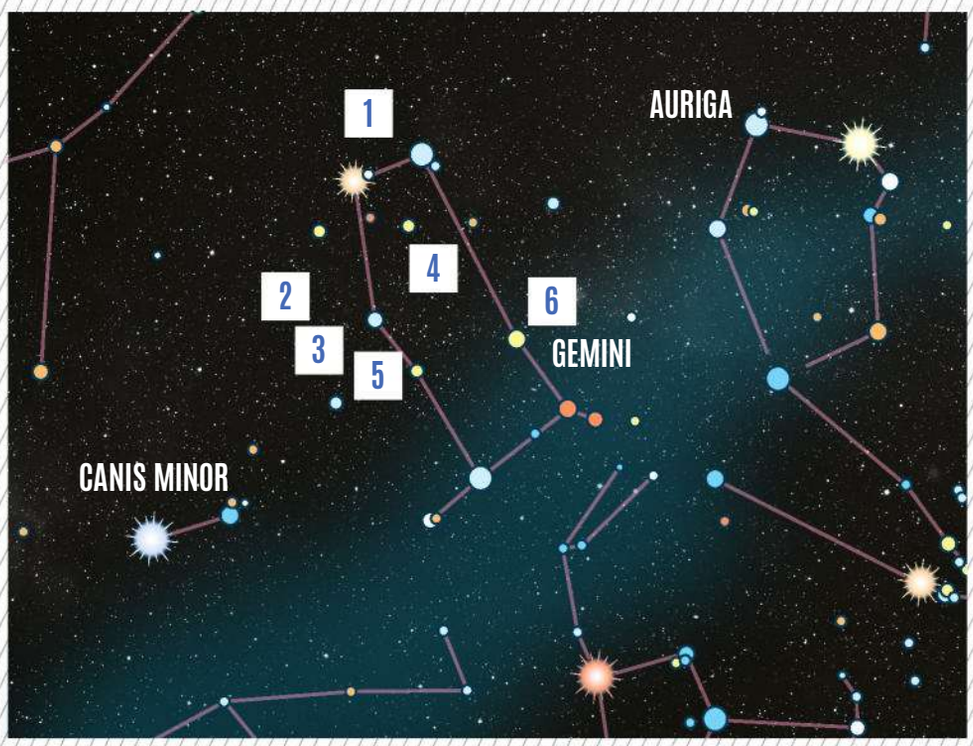
Sitting some 4,200 light years from Earth, this sparse open cluster shines at eighth magnitude. A telescope's medium-power eyepiece will show it as a loose, irregular clump of around 30 suns.

5 NGC 2339

You'll need a large telescope, dark skies and high magnification to see this 250 million light year distant galaxy. Under perfect conditions you will see hints of its tightly wound spiral arms.

6 NGC 2266

Dominated by a chain of bright stars that cuts across its centre like a mini Orion's Belt, this roughly triangular magnitude +9.5 cluster is a real treat in both medium and large telescopes.



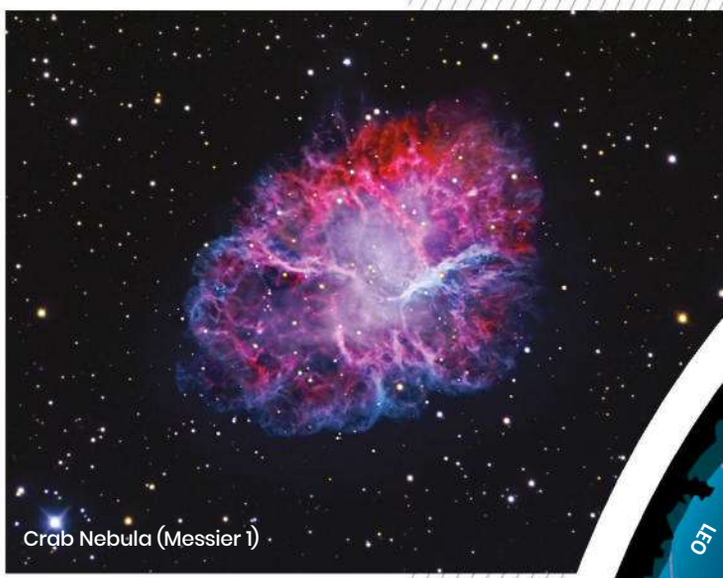
3 Eskimo Nebula (NGC 2392)

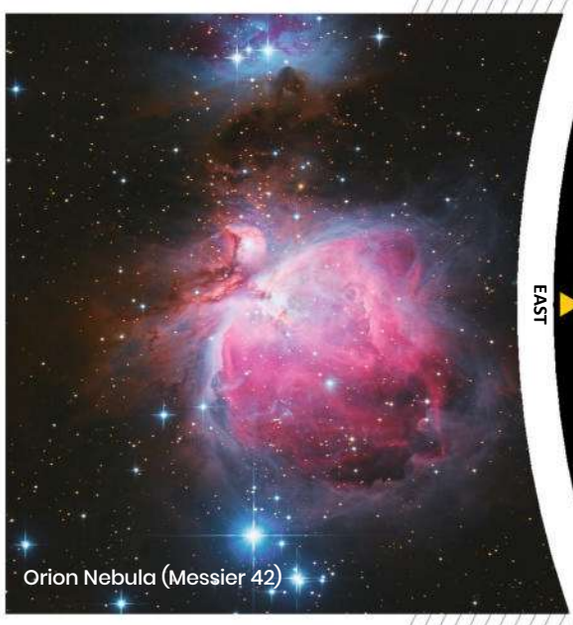
© NASA/ESA; Getty

NORTHERN HEMISPHERE

There's an impressive array of targets to enjoy, including galaxies, nebulae and vibrant double stars

If you're a fan of splitting double stars with your telescope, head over to Aries (the Ram), which makes its appearance this month, bordered by the star patterns of Taurus (the Bull), Pisces (the Fishes) and Cetus (the Whale). In particular, binary star systems Lambda Arietis, Epsilon Arietis and Mesarthim are splendid targets to resolve for astronomers with medium to large-sized telescopes. Meanwhile, orange giants Hamal (the Head of the Ram) and Botein (Little Belly) can be picked out using nothing more than the naked eye. Orion (the Hunter) is also prominent in the December skies, featuring red supergiant Betelgeuse, De Mairan's Nebula (Messier 43) and the stunning Orion Nebula (Messier 42).


Crab Nebula (Messier 1)


Orion Nebula (Messier 42)

Messier 74

Using the sky chart

This chart is for use at 22:00 mid-month and is set for 52 degrees latitude.

1. Hold the chart above your head with the bottom of the page in front of you.
2. Face south and notice that north on the chart is behind you.
3. The constellations on the chart should now match what you see in the sky.

Magnitudes

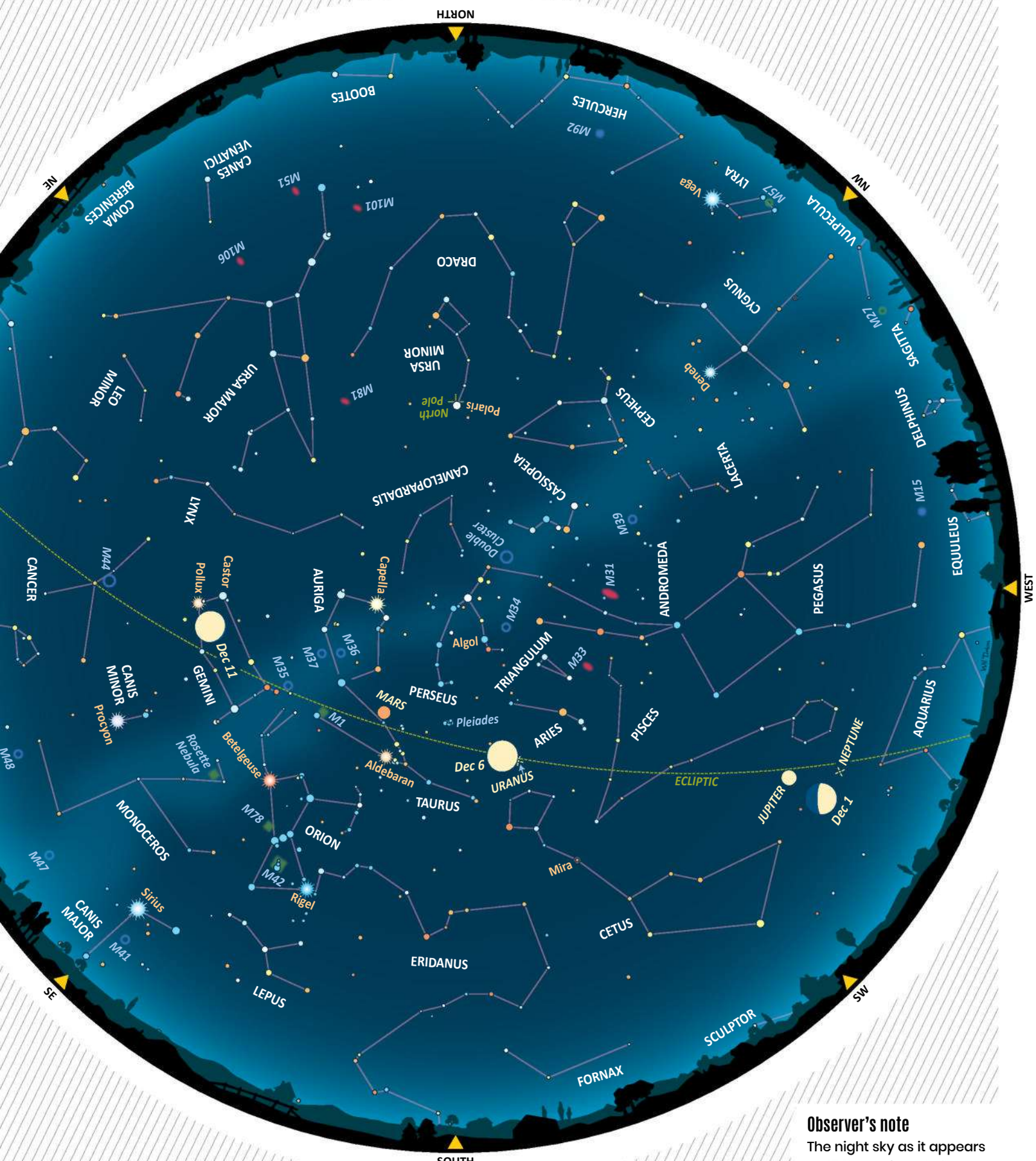
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to +0.5
- +0.5 to +1.0
- +1.0 to +1.5
- +1.5 to +2.0
- +2.0 to +2.5
- +2.5 to +3.0
- +3.0 to +3.5
- +3.5 to +4.0
- +4.0 to +4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note

The night sky as it appears on 17 December 2023 at approximately 22:00 (GMT)

© Getty

REVIEW

CANON EOS RA

This DSLR gives astrophotographers and landscape photographers alike everything they need to capture the colours in their work

Reviewed by Ollie Taylor

DETAILS

From: Canon
Price: £2,579.99 / $2,780
Type: Mirrorless
Sensor: 30.3 megapixels
Lens mount: RF, but can use EF with a converter
ISO range: 100 to 40,000
Viewfinder size and resolution: 3.2-inch 3.69m-dot OLED
Video capability: 4K
Weight: 660 grams
Size: 13.4 by 9.9 by 8.3 centimetres
Memory card type: Single SD

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WIDE-ANGLE PHOTOGRAPHY
SOLAR SYSTEM
DEEP SKY

Astrophotographers and landscape photographers looking to try and emphasise the colours of the nebulae in their work now have a serious piece of kit available to help them achieve this in the Canon EOS Ra. Differentiating from the dedicated astrophotography cameras normally used on telescopes, the Canon EOS Ra interlinks the rest of Canon's RF mirrorless system, resulting in an array of interchangeable lenses. With a familiar feel for existing EOS R users, the camera is essentially a Canon EOS R with some adjustments, meaning the unit doubles up nicely as a second camera for nightscapers who use two units.

The EOS Ra also doubles up for everyday use for those only using one camera who have a predominant interest in the night sky – albeit with a few notable minor colour casts here and there. However, being a multipurpose unit makes it an attractive product with which users can easily take daytime shots and later venture to dark-sky sites to really put the Canon EOS Ra through its paces.

The Canon EOS Ra is a camera that has been designed specifically for astrophotographers, though it can also be used for everyday photography due to Canon's in-camera white balance firmware. Astrophotographers like to be able to capture the magenta colour in nebulae when shooting deep-space objects. More recently, landscape astrophotographers have also started to implement the colour from nebulae within their nightscape scenes. The problem is that 'off-the-shelf' interchangeable-lens cameras have filters over the sensor that purposely block out the colours at this end of the spectrum, created by the gases within nebulae, alongside blocking multiple other wavelength values to create a clean, natural-looking image. This is because allowing these wavelengths to penetrate the sensor causes obscure colours and unwanted ghosting, halos and banding due to multiple sources emitting different unwanted wavelength frequencies.

The EOS Ra is currently the only full-frame mirrorless camera manufactured for greater sensitivity to colours at the red end of the spectrum, with the predominant aim to capture more 656.28-nanometre H-alpha. Canon has also taken into consideration how astrophotographers and landscape astrophotographers focus at night using manual focus and refine their focus by magnifying on a star. Considering this, Canon has created a 30x focus magnifying mode, allowing much easier fine-tuning and star sharpness precision.

Naturally, the Canon EOS Ra follows the general design and ergonomics of the EOS R series of mirrorless cameras, and apart from the 'Ra' written on the body, there's very little to distinguish it from the Canon EOS R. The Canon EOS Ra is compact and stylish, with sleek angular curves and button positioning.

When first picking up an EOS Ra from either a traditional Canon DSLR or another brand of DSLR or mirrorless camera, the positioning of dials, buttons and the general handling can seem a little strange. However, this is soon overcome, and it doesn't take long to adjust and realise that the camera's

The EOS Ra is compatible with many Canon RF lenses

The camera is well suited to astrophotography in all wavelengths

"Users can easily take daytime shots and later venture to dark-sky sites to really put the Canon EOS Ra through its paces"

layout is both unique and logical. Your hands are soon at ease with it and its smaller, lightweight design, and its handling quickly becomes the norm – so much so that picking up another camera soon after feels alien. The compatible Canon RF lenses also have a customisable control ring on the front of the lens, allowing this to be changed to aperture, shutter speed, ISO and so on to add more flexibility to camera customisation.

The handgrip is a generous size and comfortable, though the digital mode button within the typical shutter speed dial can take some getting used to, and the multifunction bar to the right of the viewfinder can get in the way for those with larger hands. However, if necessary, multifunction bars can be switched off. The Canon EOS Ra is weather-sealed, though not to the extent of traditional DSLRs such as the Canon 5D Mark IV.

The customisation is a little limited compared to some other brands, though assigning general functions to buttons or dials is simple. The typical AF-ON and AEL buttons can be converted to adjust ISO or other commands by holding the button and adjusting the dial. ISO button customisation is somewhat essential for general ease of use while gripping the camera in the dark, as opposed to relocating half of your hand and searching for a back or top-located ISO button. The quick menu, however, is not customisable, thus a few of the menu options you may want to switch over cannot be done, forcing you to customise another button.

Aside from the H-alpha sensitivity, one of the key selling points for astrophotographers is the 30x focus magnification, making focusing through a telescope easier than the typical 10x magnification. This is also useful for landscape astrophotographers and low-light photographers, especially when focusing on subjects such as the Moon's surface. It does make focusing on duller stars with wide lenses easier, though sometimes you do find yourself switching back to 10x magnification with brighter stars. When coupled with the Canon EOS Ra, fast lenses allow for autofocus to be used on stars in the dark as long as they can be seen clearly. You can simply autofocus on a bright star, then turn the autofocus off – this even works with wide-angle lenses.

Canon's touchscreen system is nothing short of perfect; it's a system that actually makes you want to use it due to how fluent it feels and the ease of controlling the

The sensor is specially designed to pick up magenta hues

camera using it, which isn't the case with some other mirrorless brands. The LCD screen rotates 360 degrees once flipped out from the body. This is highly advantageous, as for astrophotography the camera is often at obscure angles, meaning you can have the screen facing your viewing position and control the camera from the touchscreen. However, there's one big downside to the screen design. Landscape astrophotographers usually favour L-bracket plates to hold their cameras, and these get in the way of the LCD being able to flip out, and therefore rotate.

The Canon EOS Ra is the first 35mm equivalent digital camera designed specifically with astrophotographers in mind since May 2015 and the legendary Nikon D810A. Purchasing this unit is almost a no-brainer for astrophotographers, though there is the matter of conversions and where these fit in. A conversion essentially means removing the 'hot mirror' sensor that filters infrared and ultraviolet. Many companies replace it with their own infrared-cut and H-alpha-enhancing filter to allow focus to work. When it comes to landscape astrophotography, conversions usually cause stars to stretch around the edge of the frame. But with Canon designing the EOS Ra with both astrophotographers and landscape astrophotographers in mind, there's no stretching of stars with wide-angle lenses.

Canon's reworking of the sensor filters in the EOS Ra doesn't disappoint. It clearly picks up the indicated 4x H-alpha frequency so nebulae can be seen in the imagery created using it. However, these colours are not usually visible straight from the camera. When shooting landscapes at night, RGB post-production techniques are often required to extract the data. Tracking landscape astrophotography on the Canon EOS Ra also helps capture more data, increasing the intensity of nebulae colour within the image. These advanced techniques are factors that may put less experienced landscape astrophotographers off purchasing the Canon EOS Ra.

FOR

- H-alpha sensor sensitivity
- 30x focus magnification
- Brilliant aesthetics and ergonomics
- User-friendly touchscreen and LCD
- RAW file white balance firmware

AGAINST

- Low-light and high-ISO performance could be a bit better
- Possibility of red halos and ghosting
- Price of RF lenses
- Only one memory card slot

The 30.3-megapixel sensor easily holds its own, though it's difficult to understand why Canon rushed this out with a fairly old sensor, easily beaten with regards to overall landscape astrophotography image quality by cameras such as the Sony Alpha 7 III, Nikon Z6, Z7 and D850. High-ISO images are cleaner out of the aforementioned cameras. Landscape astrophotographers usually track or stack for the sky, then create a long exposure for the foreground at a lower ISO to generate a cleaner image; the Canon EOS Ra just lags behind a little on overall image rendition, ISO grain and foreground detail for long exposures.

Just six months later, Canon released an incredible low-light performer in the EOS R6 with only 20.1 megapixels; it's well documented that the lower the megapixel count, the better real-world low-light performance in the field is with current sensor technology. It's a real shame that the EOS Ra didn't capitalise on using the later R6 sensor, as this would have made it a serious landscape astrophotography powerhouse.

The battery life of the Canon EOS Ra is reasonable – and even better with the LCD brightness turned down or off while shooting. Two or three fully charged LP-E6NH battery packs should easily last most landscape astrophotographers a full night of shooting with the unit.

Another plus side to the EOS Ra is its little-known built-in software that shifts the white balance to an almost-normal tone when using the camera for purposes other than at night. The software is excellent, and although tints may be slightly different on certain colours within a scene, the built-in white balance shift software does an impressive job at making the RAW files look as if they have come out of a standard camera not designed for astrophotography, a feature impossible to replicate on a third-party conversion.

The Canon EOS Ra has another problem, though not one well documented, as the majority of deep-sky astrophotographers use multiple external filters, and therefore filter out the problem. The EOS Ra can cause magenta halos on bright objects such as stars and planets, especially Mars and the Sun if shooting in the day. It's thought this is due to the camera allowing light in from the far end of the wavelength spectrum, past 656 nanometres and towards the 700-nanometre end.

Overall, the Canon EOS Ra is an excellent first-choice camera for deep-space astrophotographers, and should definitely make the grade as a second camera for landscape and nightscape astrophotographers who understand RGB editing and how to use trackers and advanced techniques to get the best from the device. However, it's definitely not an ideal all-around choice for a solo multipurpose camera for those with only a slight interest in astrophotography or landscape astrophotography.

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CHRISTMAS GIFT GUIDE

The best presents for astronomy and space fans

Celestron StarSense Explorer 114mm Dobsonian Telescope

Cost: £299.99 / $349.95
From: Celestron, Wex Photo Video and other good retailers

1 Celestron has reinvented the tabletop Dobsonian telescope with StarSense Explorer – the first tabletop Dobsonian that uses your smartphone to analyse the night sky and calculate its position in real time. The 114mm-aperture Celestron StarSense Explorer is ideal for beginners thanks to the app's user-friendly interface and detailed tutorials. It's like having your own personal tour guide of the night sky.

Celestron NexStar 5SE

Cost: £999.99 / $799.00
From: Celestron, Very and other good retailers

2 Celestron's signature orange-tube NexStar series combines advanced features and excellent optics in one easy-to-use computerised system. The NexStar 5SE is the perfect choice for your first Go-To telescope, offering striking views of Saturn's rings, the cloud bands on Jupiter, geographic features on the Moon and much more. The NexStar 5SE's unique, patented single-fork arm mount is perfectly portable and makes setting up quick and easy. Aligning the telescope is simple thanks to Celestron SkyAlign technology.

Diamonds Everywhere

Cost: £16.99 / $24.99
From: Collins

3 Feed cosmic curiosity with *Diamonds Everywhere* by astronomer Tom Kerss, a stunning photographic guide to 101 facts about the universe. Did you know that there are probably more stars in the Milky Way than every human that has ever been born? That some stars are so cool, you could touch them without burning your hand? Or that the Andromeda Galaxy and the Milky Way are destined to collide? This book is the perfect Christmas gift for earthlings who love to learn.

ESA Patch Beanie

Cost: €22.90 (approx. £19.95/$24.49)
From: esaspaceshop.com

4 A fitting beanie for space enthusiasts featuring the official European Space Agency (ESA) patch worn by ESA astronauts. Made from 100 per cent acrylic, with a one-size-fits-all approach, this beanie is designed with everyone in mind. The beanie is available in either royal blue or navy blue and the patch includes the flags of 22 ESA Member States. The ESA patch was redesigned in 2020 to include two Associate Members, Latvia and Slovenia, and one Cooperating State, Canada.

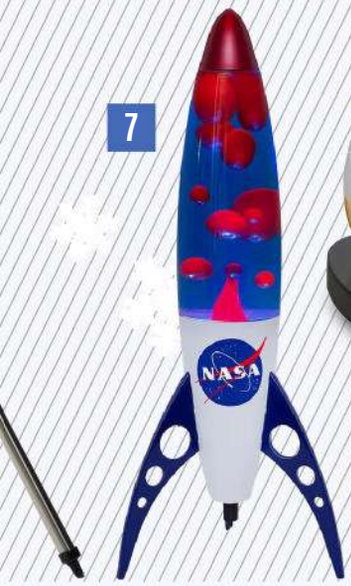
Celestial Buddies

Cost: From £18.22 / $21.99
From: celestialbuddies.com

5 Have you ever wanted to give the entire Solar System a great big hug? Now you can with these adorably squishy celestial buddies. Each member of the Solar System

6

"This little sculpture is guaranteed to make a big statement"



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has been transformed into a unique character, from feisty Mars to our loyal Moon, and even Pluto and Charon haven't been left out. Each buddy comes with its own little tag consisting of entertaining and interesting facts, making them both fun and educational.

Perseverance 2020 Mars Rover Illuminated Sculpture

Cost: £119.96 / $139.98
From: Bradford and Amazon

6 Celebrate the monumental triumph of the Mars rover Perseverance with this iconic handcrafted sculpture. This hand-painted replica features adjustable accessories, including the extendable metal robotic arm and a fully rotating replica camera mount. This little sculpture is guaranteed to make a big statement, with built-in LED lights illuminating the rover's undercarriage and wheels. The base is adorned with full-colour images of Mars, as well as the NASA logo and the launch date of the mission.

NASA Retro Galaxy Lamp

Cost: £39.99 / $46.99
From: NASA Depot

7 Add some nostalgic flair to your home or office space with this NASA Retro Galaxy Lamp. This impressive rocket stands 50 centimetres (19.7 inches) tall and is the perfect gift for the space – or lava lamp – enthusiast in your life. The lamp requires an R50 E14 40W bulb, which is included and powered by UK mains. Simply unbox, assemble, turn on and wait for the mesmerising wax shapes to appear.

Deluxe Globe Decanter Set

Cost: £59 / $89.95
From: MenKind and Amazon

8 Fuel your adventurous spirit with this decanter shaped like a classic globe. The weight of the world – or in this case approximately 850 millilitres – rests on a sleek wooden cradle. The blown-glass decanter also contains a detailed ship inside and is accompanied by two matching glass tumblers, each embellished with continental markings.

Criacr Planet Neon Light

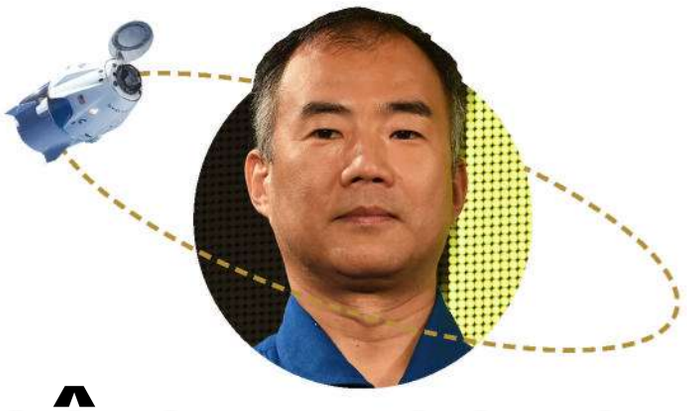
Cost: £9.99 / $11.98
From: Amazon

9 Add a touch of neon flare to your home with this quirky ringed planet light. Available in pink and blue.

Swatch Space Collection Watch

Cost: £155 / $185
From: Swatch

10 It's time to explore the Swatch Space Collection, featuring five space-age watches with designs influenced by NASA and its iconic spacesuits. This particularly striking watch's design was influenced by the orange Advanced Crew Escape Suit, affectionately known as the pumpkin suit, but there are also other variants in more muted blue, white and grey.



SÔICHI NOGUCHI

This Japanese astronaut has flown aboard three different spacecraft and the ISS

Noguchi was born in 1965 in Yokohama, Japan. He joined the Scouts when he was nine, an organisation he credits with his early experience learning the importance of teamwork. In 1989 he earned a bachelor's in aeronautical engineering at the University of Tokyo. He then received a master's degree in aeronautical engineering in 1991 and a doctorate in advanced interdisciplinary studies in 2020, also from the University of Tokyo.

In a 2010 interview with NASA, Noguchi said both science fiction and fact inspired his decision to become an astronaut. "I really liked all the rockets and spacecraft and space adventures when I was in childhood," he said. "When I was a high school freshman I saw the Space Shuttle STS-1 go up on television and I thought, 'Wow, this is a great career; I wonder if I can someday be a space traveller'."

Noguchi was chosen as an astronaut candidate by the Japan Aerospace Exploration Agency in 1996. After two years of training at NASA's Johnson Space Center, Noguchi was qualified for flight assignments aboard the Space Shuttle in 1998. That same year he also participated in crewed space systems training at the Yuri Gagarin Cosmonaut Training Center in Russia. He then continued advanced training with NASA while working on the Japanese Experiment Module development tests.

In April 2001 he was assigned as a crew member for NASA's STS-114 mission that launched in 2005, during which he spent two weeks in space and conducted three spacewalks. As a mission specialist aboard the Space Shuttle Discovery, Noguchi was a member of the first crew to launch after the disastrous loss of the astronauts on the Space Shuttle Columbia in 2003. In the crew's first post-mission briefing, Noguchi was one of many members of the crew and control teams to recall the previous mission's tragedy. "Columbia was very close in our minds," Noguchi said.

Noguchi followed his first mission with a longer stay on the International Space Station (ISS) in 2009 as part of Expedition 22/23. On 20 December 2009, he launched in a Soyuz TMA-17 spacecraft from Baikonur Cosmodrome in Kazakhstan, returning 163 days later in June 2010. Noguchi later served as a mission specialist on the Crew-1 SpaceX Crew Dragon, the first fully fledged private crewed mission to travel to the ISS. It launched on 16 November 2020. The Crew-1 astronauts named the spacecraft 'Resilience' in recognition of the challenges that people faced and overcame during the COVID-19 pandemic of 2020. His first spacewalk as flight engineer of Expedition 64 set a world record for the longest gap between spacewalks – an interval of 15 years and 214 days.

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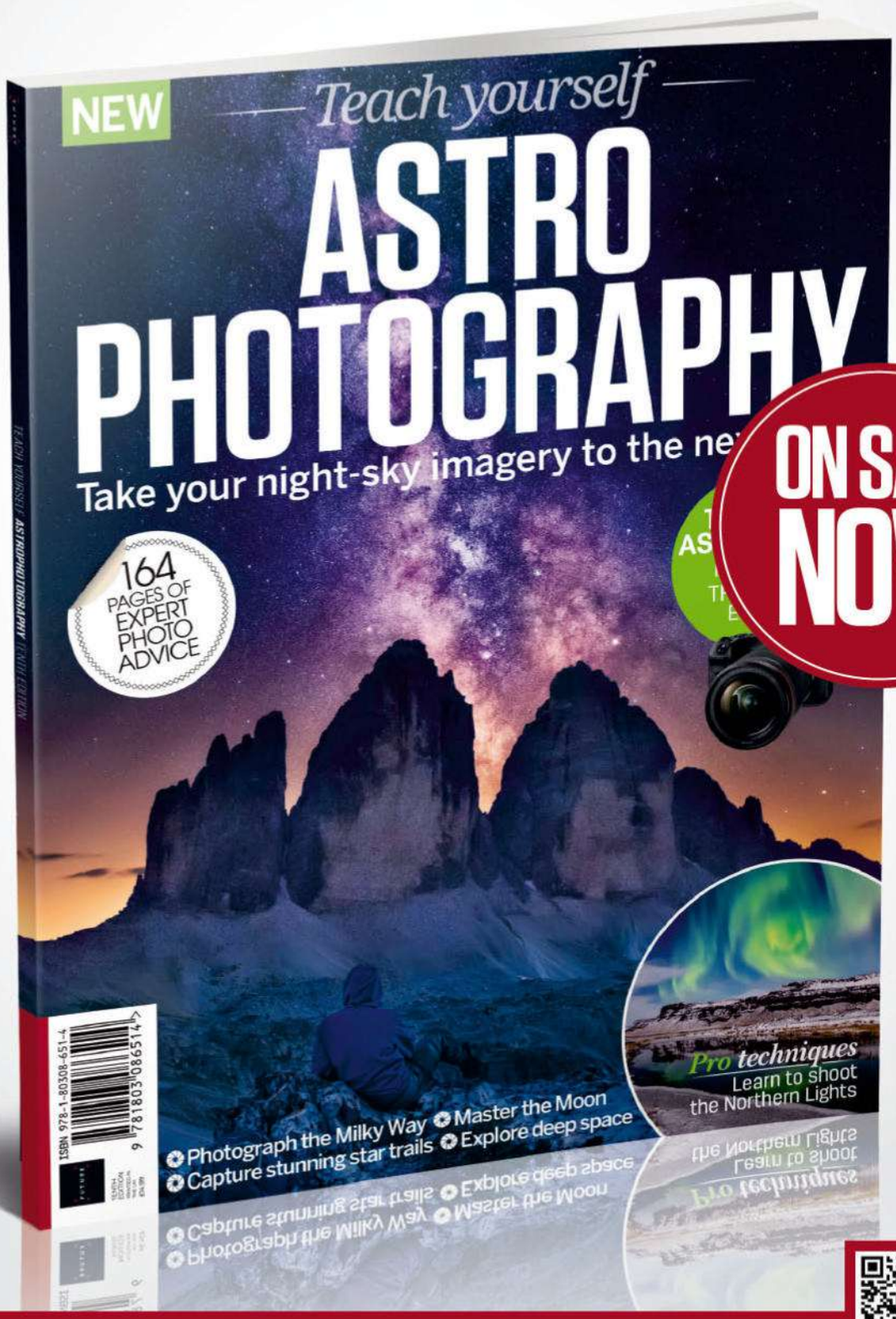

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